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This Association, as a body, is not responsible for the statements or opinions of any of its members.

REPORT OF COMMITTEE ON METER RATES.

[*Read September 9, 1914.*]

TO THE NEW ENGLAND WATER WORKS ASSOCIATION:

Your Committee on Meter Rates presents the following preliminary report with the request that it be made the subject of general discussion, and with a view to the preparation of a final report by the committee after it has had the benefit of such discussion by the members.

REPORT.

Nine years ago a committee, of which the late Freeman C. Coffin was chairman, presented a most admirable report on the subject of meter rates.* This report took up the matter in a thoroughgoing and logical manner, and the justice of the method proposed has been generally recognized. The basis of the method consisted in a flat meter rate for all quantities to be made in addition to a service charge, the latter depending upon the frontage of the property. The service charge was to be collected in all cases whether water was drawn through the meter or not. In connection with this service charge, which would give the works an assured income, the rates for metered water could obviously be much lower than would otherwise be possible. These

* JOURNAL N. E. W. W. ASSOC., *19*, 1905, p. 322.

principles have found application in part in many of the water rates that have been adopted in the last years.

On the other hand, some of the methods proposed in the Coffin report differed radically from current practice. This was especially true of that portion of it which made the service charge dependent upon frontage. To adopt this method would make a fundamental change in the basis of existing rates.

Notwithstanding a general recognition of the excellence and justice of the method, the radical change involved in adopting it has served to prevent its general use. With a few unimportant exceptions it has not been adopted.

The matter is now taken up by your committee with the thought of presenting a procedure embodying the most useful features of the Coffin report, but arranged so as to diverge less from current practice, and so that the proposed schedule may be adopted with a minimum disturbance to existing rates and conditions.

To carry out this idea, your committee suggests a standard schedule in a form given below, which it believes to be adapted to general use. The committee suggests that this schedule be freely discussed by the members of the Association and modified as found desirable after such discussion, and finally, that it be adopted by the Association as a standard schedule representing an ideal towards which members may work whenever meter rates are being revised, and which may be incorporated in whole or in part as may be found feasible and advantageous in such revised rates.

In this schedule the sliding scale of rates is recognized, and three rates are provided. The schedule does not fix these rates. They are left to be fixed for each case as may be necessary to produce the required revenue. The quantities of water per annum, per quarter, or per month to which the three rates are applicable are defined and made uniform by the schedule.

In addition, a service charge is provided. The service charge was an essential feature of the Coffin schedule, but the service charge now proposed rests upon a different basis and one which the committee believes will more readily lend itself to adjustment to existing conditions.

In the event of there being local objection to using a service

charge, the committee proposes an alternate arrangement, under which the amount of the service charge is applied as a loading to the price for a small amount of water first sold from each service, thus making in effect a fourth and higher rate, for use only where no service charge is made.

DIVISIONS OF THE SLIDING SCALE.

It is proposed to make only three divisions of the sliding scale. At the present time there are many schedules in effect, with more and even with several times this number of divisions. The committee believes that in general more than three divisions are unnecessary and undesirable. Too many rates add to the complexity of the schedule, to the labor of applying it, and to the difficulty of understanding and comparing rates.

The committee proposed that all water up to 300 000 gal. per annum (equal to 822 gal. per day, or to 40 000 cu. ft. per annum, or 10 000 cu. ft. per quarter) shall be charged for at the first or highest rate. This rate for convenience will be called the Domestic Rate. The quantities of water covered by it will include substantially all water used by private residences, and also much of the water used by small hotels and smaller commercial and industrial establishments.

The second or Intermediate Rate will apply to quantities in excess of 300 000 gal. per annum up to 3 000 000 gal. per annum.

The third and lowest rate will be called the Manufacturing Rate and will apply to all water in excess of 3 000 000 gal. per annum from any service (equal to 8 220 gal. per day, or to 400 000 cu. ft. per annum, or 100 000 cu. ft. per quarter).

It is recommended that the price per 1 000 gal. or per 100 cu. ft. be, in most cases, an even number of cents, omitting fractions, and that the intermediate price for water be to the nearest cent midway between the average and the mean proportional of the domestic rate and the manufacturing rate. By this rule the intermediate rate is definitely fixed at an amount midway or a little below midway between the domestic and manufacturing rates. There is, therefore, no need of discussing the amount of this rate. Consideration may be concentrated on the two main points in the schedule, the domestic rate and the

manufacturing rate; and with these fixed, the intermediate rate will follow by fixed rule, and will be certain to be appropriate in connection with the others.

AS TO THE AMOUNT OF SLIDE IN THE SCALE.

There are many scales of meter rates in effect at the present time in which the highest rate charged for the first water is unduly large in comparison with the lowest rate charged for the largest quantities. It sometimes happens that there is a ratio of ten to one or more between these rates. The committee disparages so great an amount of slide, and recommends that the lowest price for water shall rarely be less than half of the domestic rate.

Where the price for manufacturing water is 75 per cent. or more of the domestic rate, it is suggested that the intermediate rate may be omitted and that the manufacturing rate then apply also to the water that would otherwise be sold at the intermediate rate. If the rate for manufacturing water is 100 per cent. of the domestic rate, both limits disappear and one flat rate will apply to all quantities.

Many works now make a flat rate for water. A flat rate with no slide was recommended in the Coffin report. A flat rate can only be fairly applied in connection with a proper service charge. With an adequate service charge, the reason for the sliding scale is greatly reduced, and there is much to be said in favor of the flat rate. The committee does not wish to urge the sliding scale in preference to flat rates where such are now used, and the proposed scale lends itself to use either with or without the sliding scale.

The principal reason for the sliding scale is that it costs more to distribute water to many small takers than to a few large ones. From the standpoint of cost only, the best way to take care of this excess cost is by means of the service charge. But to do this adequately would mean the adoption of a service charge so large as to be burdensome to the smallest takers. These smallest takers are not profitable to the system at low rates even with such service charges as the committee now proposes. Nevertheless they must be supplied, and it seems to be a wise policy

to supply them at low rates, making the larger takers carry a proportion of the excess cost of supplying small consumers. The sliding scale affords a means and perhaps the best means of effecting this adjustment.

In view of the general use of the sliding scale at the present time, and in view also of some strong arguments in favor of a moderate amount of slide in the scale, the committee does not see its way clear to recommend giving up the sliding scale, and only recommends that the amount of slide be limited to moderate proportions and that the points where change in rate takes place be made definite and uniform.

SERVICE CHARGE.

The committee believes that it is essential to make a substantial service charge in order to secure equitable rates for all. The service charge may be naturally made up of several parts. It suggests that the procedure to be followed in determining the amount of the service charge be as follows:

First, that the average amount of money invested by the works in the service pipe and meter be ascertained. Where the works furnish the service pipe to the curb line, and the meter, the normal cost seems to be about $25 per service. Where the taker pays for the service pipe and the works furnish the meter, the normal cost seems to be about $10 for a $\frac{5}{8}$-in. meter in position. The committee suggests that 10 per cent. of this cost be taken as the first part of the service charge. That is to say, that $2.50 per annum be used where both service and meter are paid for by the works; $1.00 per annum where the meter only is furnished by the works, and that this part of the charge disappear where both pipe and meter are paid for by the taker. The committee believes that on the whole 10 per cent. is a fair allowance for the depreciation in the service pipe and meter, and for the interest on the money invested in them. The structures are not long-lived, and occasional repairs are needed. A reasonably approximate figure is sufficiently close, and 10 per cent. is used in this way.

The figures mentioned for cost of service and meter are believed to be representative, but they should be increased or de-

creased according to the ascertained average costs under local conditions. Round figures should be used in all cases as a matter of convenience, and because precision is unnecessary, and because it cannot be reached in most cases. For meters larger than the five-eighths domestic size, correspondingly larger figures should be used.

Second, a sum per annum representing approximately the cost of reading the meters, keeping the meter records, making bills, and collecting the money. The amount of this item depends upon the frequency upon which meters are read, and upon local conditions; for ordinary domestic services where meters are read once a quarter, $1.00 per annum may be a sufficient allowance. This figure may also be used without substantial injustice for services of all sizes, because when meters are read monthly the quantities are usually larger and the cost of meter reading becomes an inappreciable fraction of the bill.

Third, an amount which will represent the approximate average value to the works of the water that passes a domestic meter without being registered. The normal service of a domestic meter for one day may be assumed to consist of passing 200 gal. of water, more or less, in about two hours, the whole time being made up of many short intervals during the day. During the remaining twenty-two hours no water will ordinarily be flowing. If the service pipe and plumbing are perfectly tight, no water will pass during those twenty-two hours; if there is a leak of such size that the water lost by it will turn the meter, then the meter will register the flow throughout the twenty-four hours, and all the water passing will be recorded, except that there may be some slip in the meter at a low rate. If there is a leak in the service or plumbing which allows water to escape, but in amount so small that it does not serve to move the disk or piston of the meter, then the amount of water lost by such leakage in the twenty-two hours when the piston or disk is not moving will be entirely unrecorded. Probably no meter in ordinary service will register a flow of less than 100 gal. in 22 hours. Many meters in actual service will allow much larger quantities to pass without registering. It is probable that the plumbing in every house has leaks at times, through defective washers in

the faucets or automatic valves which permit the loss of water in amounts too small to be recorded. In some houses such loss is always taking place. In the aggregate the amount of this unrecorded leakage from plumbing is large. It probably furnishes the greatest single reason why the amount of water registered by meters never approximates closely the total quantity of water furnished by the system.

Water lost in this way is running at a steady rate throughout the twenty-four hours, and increases but slightly the peak load of the plant. It can, therefore, be supplied at the lowest relative cost, and for the purpose of this estimate should be reckoned at the lowest rate charged for any water that is sold.

The amount lost per service will range from nothing to 100 gal. per day, and occasionally to much larger quantities. Assuming an average of 50 gal. per day per service at a minimum price of 10 cents per 1 000 gal., the value of water so lost amounts to $1.82 per service per annum.

There are no adequate data upon which this loss can be computed, and the committee sees no way of securing such data at this time. Nevertheless it believes that the matter is an important one and that a substantial allowance should be made for such losses. It suggests for the present the use of $2 per annum for this item.

Upon this basis the service charge will amount to the sum of these parts, namely, first, 10 per cent. of the average investment of the works in service pipe and meter; second, $1 per annum for reading meters, billing, and collecting; third, $2 per annum for the probable value of unregistered water. For a domestic service with $\frac{5}{8}$-in. meter, the ordinary service charge may properly be $3, where service and meter are paid for by the taker; $4 where the meter is furnished by the works; and $5 or $6 where both meter and service pipe are paid for by the works, the lower figure being used where the average cost of a service pipe is under $15, the higher where it is greater than $15.

The figures used in the above paragraphs should be considered only as general approximations, to be modified to meet established local conditions, or upon more complete data. The committee suggests that the *method* is of first importance and should

be first discussed and settled, and that the values to be then used under it should always be selected with reference to the conditions in each plant for which a service charge is to be established.

The charges for larger services will readily be reached by the application of the same methods, and the committee does not suggest any values for them at this time.

AS TO THE MANNER OF APPLYING THE SERVICE CHARGE.

The committee recommends that the amount determined by the use of these methods, raised or lowered to a convenient round figure, should be charged for each service; that this charge should be made in all cases whether water is drawn or not; and that all water drawn from the service should be charged at current rates in addition thereto.

Many works at the present time make a charge for meter rent. In such cases, and otherwise if desired, the service charge may be called "meter rent," the amount being taken as the amount determined for the service charge.

The method of making a service charge separate from and in addition to the charge for water registered is the most convenient and equitable way of distributing the costs considered in the above paragraphs where they belong, and the committee recommends it for use in all cases.

ALTERNATE PROCEDURE.

Where there is local objection to making a service charge (even though called meter rent), the following alternate and less desirable procedure may be used.

The amount that would be a fair service charge is computed as above. This amount is divided by 60 and the result to the nearest even cent is added to the domestic rate, and this new rate (which may be called a loaded or maximum rate) is applied to the first 60 000 gal. of water per annum drawn from each service. If cubic feet are used, the amount is divided by 80, and the result to the nearest even cent is added to the domestic rate per 100 cu. ft., and the increased rate is applied to the first

8 000 cu. ft. per annum used from each service. In connection therewith, a minimum rate must be established. This minimum rate may be about $3 more than the computed service charge. This double procedure of loading the rate for the first quantity of water sold from each service and of establishing a minimum rate will accomplish in a rough way the general purpose of the service charge. It is less satisfactory because it is less fair as between the various small consumers drawing quantities of water that will be affected by it. It is as fair to the works and to the larger consumers because the loading of the first quantity of water sold by the method described will produce a sum nearly equal in the aggregate to that which would otherwise be directly charged for the services.

GALLONS OR CUBIC FEET.

It is most unfortunate that two units of measurement are in common use. It would be much better if one could be discarded. More than three fourths of meters now in service record the quantity in cubic feet. According to replies to the committee's inquiries, schedules of water rates are about equally divided between cubic feet and gallons. The Coffin committee recommended the use of cubic feet. The number of meters now being sold to register in gallons is increasing much faster than the total number sold. This indicates a gain in popularity of the gallon. There is much to be said in favor of each of these units. Replies to the circular letter of the committee indicated very evenly divided preference. In view of this condition, and in view of the further fact that members of the committee have different preferences, it is not thought best to attempt to recommend at this time that either unit shall be used to the exclusion of the other. The committee recommends further general discussion of this subject, and suggests after such discussions that a vote might be taken to show the preference of the members.

It is absurd that two units should continue in general use. The advantages of adopting either one would be vastly greater than any possible advantage in either. It would seem that the Association could determine which it prefers and throw its influence toward its universal adoption. The committee feels

that this should be done by action of the whole Association and not by a committee.

In the interest of economy of labor, it is obviously desirable that the same unit should be used in any system for both meter registers and schedules. Thus the use of meters reading in cubic feet, with a schedule of rates in gallons, is undesirable and should be avoided by changing as rapidly as is possible so that both are on the same basis.

FORMS OF SCHEDULE.

The committee proposes the following form for a schedule for meter rates:

For each service supplied by ¾-in. meter there shall be a charge for the service and meter per annum of $\$$____

In addition thereto, for all water drawn there shall be charged:

	Cents per 1 000 Gal.
For the first 300 000 gal. of water per annum, or any part thereof, the Domestic Rate of	_____
For water in excess of 300 000 gal. and under 3 000 000 gal. per annum, the Intermediate Rate of	_____
For water in excess of 3 000 000 gal. of water per annum, the Manufacturing Rate of	_____

The prices to be written in the schedule should be fixed in each case by the local authorities to meet local conditions, and to produce the required revenue, and the committee makes no suggestion as to how great they should be. It is further the intention that cubic feet shall be substituted for gallons if desired, the numbers being divided by 7.5, so that the actual quantities paid for under each rate will not be changed; also that the rates may be stated as semi-annual, the numbers being divided by 2; or as quarterly, the numbers being divided by 4; or as monthly, the numbers being divided by 12.

It is to be recognized that a monthly rate with one twelfth the quantities, with varying rates of monthly use, will produce in some cases slightly different annual results from the corresponding annual rate, but it is recommended that such difference be disregarded, that the rates be made for whatever period meters

are read, and that each record period be considered by itself in computing the charge.

A schedule under the alternative and less desirable arrangement, avoiding the term "service charge" or "meter rent," would read as follows:

Minimum charge for service with ¾-in. meter, per annum,	$____
	Cents per 1 000 Gal.
For the first 60 000 gal. of water per annum, or any part thereof, at the Maximum Rate of	____
For all water in excess of 60 000 gal. and under 300 000 gal. per annum, the Domestic Rate of	____
For all water in excess of 300 000 gal. and under 3 000 000 gal. per annum, the Intermediate Rate of	____
For all water in excess of 3 000 000 gal. per annum, the Manufacturing Rate of	____

METER RATES IN FORCE.

The committee asked for schedules of meter rates by a circular letter addressed to all members of the Association. A large number of rates were received from members in compliance with this request. From these rates a calculation was made of the annual charge for a quantity of 10 000 gal. drawn at a uniform rate throughout the year, and for 30 000, 100 000, etc., up to 10 000 000 gal. per annum. In computing these amounts when a discount was allowed for prompt payment, it was assumed that this discount would be claimed by 0.9 of the takers; and 0.9 of such discount was, therefore, deducted from the computed amounts. In connection with these rates a statement was obtained from each plant showing whether the service and meter were paid for by the department or by the taker, or whether its cost was divided between them, and in all cases showing the approximate average amount paid by the plant on account of each new service and ⅝-in. meter. The amounts paid by different works for service and meters range from nothing to over $50 per service. The normal cost of the service from the main to the curb line, and of furnishing and setting a meter as shown by the replies, is about $25. The general average is

10 per cent. greater, mainly because in a few cases very high costs were reported. A great majority of replies gave average costs between $20 and $30; a few were under $20, and a few between $30 and $50, and some were over $50, these representing unusually difficult local conditions.

The divergence between the practice of different works in respect to bearing the cost of service pipes and meters must be taken into account in some way in order to compare properly the meter rates used in connection with them. The simplest way of doing this is to deduct 10 per cent. of the average cost to the works of each service from the amount computed by the schedule for each quantity. This course is followed and the annual rates that follow are thus reduced by an amount equal to 10 per cent. of the work's contribution to the cost of each service. Obviously in applying any rates deduced from these figures to a particular case, it will be necessary to add one tenth of the corresponding contribution to the works to the cost of services in that plant.

The committee believes that meter rates, where most of the services are metered, may be more safely taken as an indication of good practice than rates in those cities where the meter system has been used to only a limited extent. In them, most of the revenue is derived from meter rates. There have usually been discussions of the equity of the meter rates as between different classes of takers, and it may be assumed that in most cases the rates have been reduced during a term of years to fairly satisfactory shape. On the other hand, where meters are used to only a limited extent, it frequently happens that schedules of rates are in force that are not well adapted to the service, and their inconsistencies have not been removed because of the limited use that has been made of them. With this in mind, fifty representative reports were selected for study. In each of these more than 50 per cent. of the services were metered; most but not all of the selected works were in New England.

It would be unfair to speak of the results so obtained as the average meter rates for New England conditions, or of any conditions, because the rates in different works differ considerably in form and amount, and another selection of fifty cities equally representative would give somewhat different results. The

results are nevertheless believed to be in a general way representative of present practice.

An interesting comparison may be made with a compilation of meter rates by Mr. George W. Biggs, Jr., chief engineer of the American Water Works and Guaranty Company. This compilation shows the amounts that would be paid for various annual quantities of water in 146 works, about half of them municipally owned works, the others being water companies. In Mr. Biggs' figures, no deduction is made on account of the contribution of the works toward the cost of the service and meter. Obviously an allowance must be made for this item to make the results comparable with those obtained from the fifty rates investigated by your committee. In the absence of information as to what the average contribution has been, it is assumed that it has been $12.50 per service, this being about one half of the normal total cost per service, and a deduction of 10 per cent. of this, or $1.25 per annum, has been made from the figures compiled by Mr. Biggs. This correction is sufficiently close for practical purposes, and any error in it will not have an important influence on that which follows. As Mr. Biggs' quantities were not always the same as those for which the committee's calculations have been made, interpolations have been made which are sufficiently accurate.

It appears that the average amount of slide in the scale for which data were collected by Mr. Biggs, representing works all over the United States, is somewhat greater than in the fifty scales examined by your committee. For annual quantities from 30 to 300 000 gal., the average from 146 cities all over the country is distinctly higher than the average for the fifty works mainly in New England. On the other hand, with annual quantities above 1 000 000 gal., the order is reversed, and the average rates deduced from the 146 cities are lower.

On the whole, the two series of results show surprisingly little divergence. On an average, the slide begins to take place at about the same point, and except for small differences above mentioned the amount of slide is nearly the same in both cases.

It is possible to find rates to be inserted in the schedule which the committee now proposes which will produce charges for

the different amounts of water drawn corresponding approximately with those indicated by the two sets of data. Upon trial it is found that a service charge of $3 per annum (plus 10 per cent. of the cost of the service pipe and meter to the works), a domestic rate of 21 cents per 1 000 gal., an intermediate rate of 16 cents, and a manufacturing rate of 11 cents, produce amounts which fall between the two sets of data above mentioned for nearly all quantities, and correspond well with both of them.

These rates may thus be taken as representing in a general way, and with a fair degree of accuracy, the present average American practice in meter rates.

The three sets of rates are shown in the following table and graphically on a diagram. This shows the total charge in dollars per annum under domestic rates for various drafts, and also the average price per 1 000 gal. for all drafts up to ten million gallons per annum.

COMPARISON OF METER RATES.

		50 selected Works with most of their services metered, less 10 per cent. of cost of services.		146 Works compiled by Mr. Biggs, less $1.25 per service per annum.		Rate of $3 + 0.21 Dom. + 0.16 Inter. + 0.11 Mfg.	
Annual Gallons.	Qantity. Cu. Ft.	Amount of Bill.	Cents per 1 000 Gal.	Amount of Bill.	Cents per 1 000 Gal.	Amount of Bill.	Cents per 1 000 Gal.
10 000	1 330	$5.22	52.2			$5.10	51.0
30 000	4 000	7.05	23.5	$10.50	35.0	9.30	31.0
100 000	13 330	22.80	22.8	27.00	27.0	24.00	24.0
300 000	40 000	63.90	21.3	69.00	23.0	66.00	22.0
1 000 000	133 000	180.00	18.0	180.00	18.0	178.00	17.8
3 000 000	400 000	471.00	15.7	435.00	14.5	498.00	16.6
10 000 000	1 330 000	1 370.00	13.7	1 200.00	12.0	1 268.00	12.7

The committee limited its study to quantities under ten million gallons per annum with an average annual charge of about $1 300 because this limit is high enough to include all but a very few of the largest takers. Special considerations often control the rates made to those using more than this amount of water. These considerations are always of local character, and the committee has not thought it necessary to extend its study to existing rates for larger quantities.

It suggests tentatively that if it is thought necessary to make a fourth and lower rate that it be called a *special rate*, and that

it be made to apply only to quantities in excess of 30 000 000 gal. per annum.

METER RATE SHEET.

As a convenient means of plotting meter rates and of serving as a basis for comparing the rates in different cities, and of comparing proposed rates with present rates, a meter rate sheet has been prepared on which may be conveniently plotted the average rates paid by consumers drawing different quantities of water per annum. This sheet has a logarithmic scale which permits all the quantities and rates occurring in ordinary practice to be shown with sufficient accuracy in a relatively small size. This sheet has been drawn in two forms, one for cubic feet and the other for gallons. In all other respects the sheets are the same and are interchangeable. In order to plot a schedule of meter rates, a list of quantities per annum ranging from the smallest to the largest is taken and the payment for each is computed. If the bills are made quarterly, the quantities in the list are divided by 4, or if monthly, by 12. If necessary the quantities are changed from cubic feet to gallons. The rates of the schedule are then applied to these quantities. If upon a monthly basis, the monthly bill is multiplied by 12 to produce the annual payment for that quantity of water. If a discount for cash is allowed, 0.9 of it is deducted on the assumption that 0.9 of the customers will avail themselves of it. From the sum so found is deducted 10 per cent. of the average investment of the works in service pipe and meter, if any. The remainder represents the return to the works for the assumed quantity of water. This is divided by the quantity of water for which the calculation is made. The result is the average price per thousand gallons (or per hundred cubic feet) paid by a consumer drawing that quantity in the course of a year. When the average cost corresponding to each term in the series of quantities has been found, they are plotted upon the paper and the points are connected up by straight or curved lines.

On Fig. 1 presented herewith are plotted the averages of the rates in the fifty cities considered by the committee and in the 146 cities compiled by Mr. Biggs, and also those correspond-

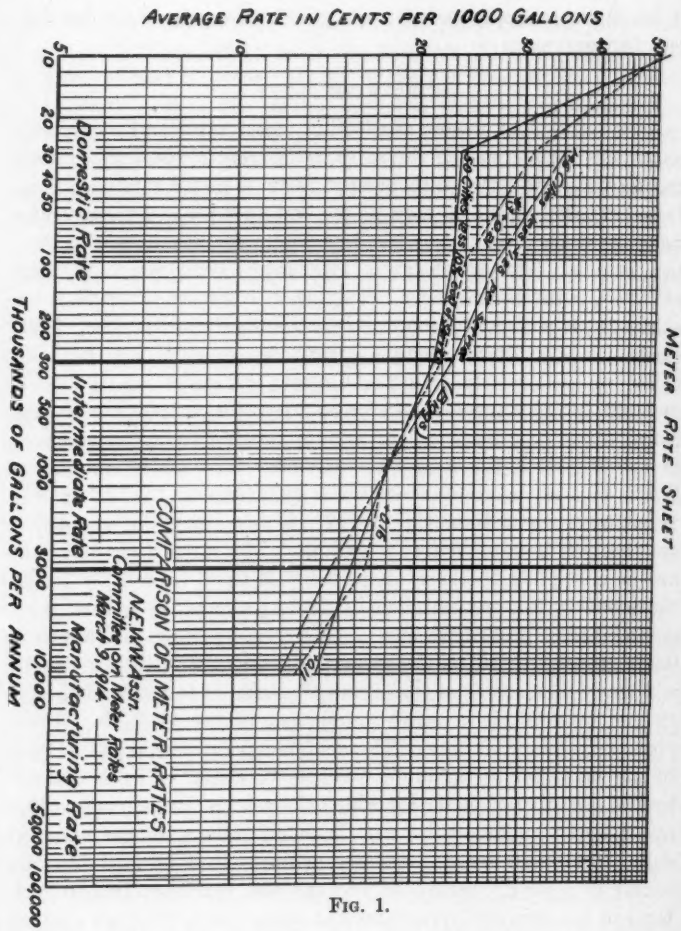
AVERAGE RATE IN CENTS PER 1000 GALLONS
5 10 20 30 40 50
Domestic Rate
Intermediate Rate
Manufacturing Rate
THOUSANDS OF GALLONS PER ANNUM
5 10 20 30 40 50 100 200 300 500 1000 3000 10,000 50000 100,000
COMPARISON OF METER RATES
N.E.W.W.Assn. — Committee on Meter Rates March 9, 1914.
METER RATE SHEET

FIG. 1.

ing to a service charge of $3, plus 10 per cent. of the cost of the service, with 21 cents per thousand gallons for domestic, 16 cents for intermediate, and 11 cents for manufacturing rates.

On Fig. 2 are plotted nine representative schedules from New England cities. It is seen from these that in most cases

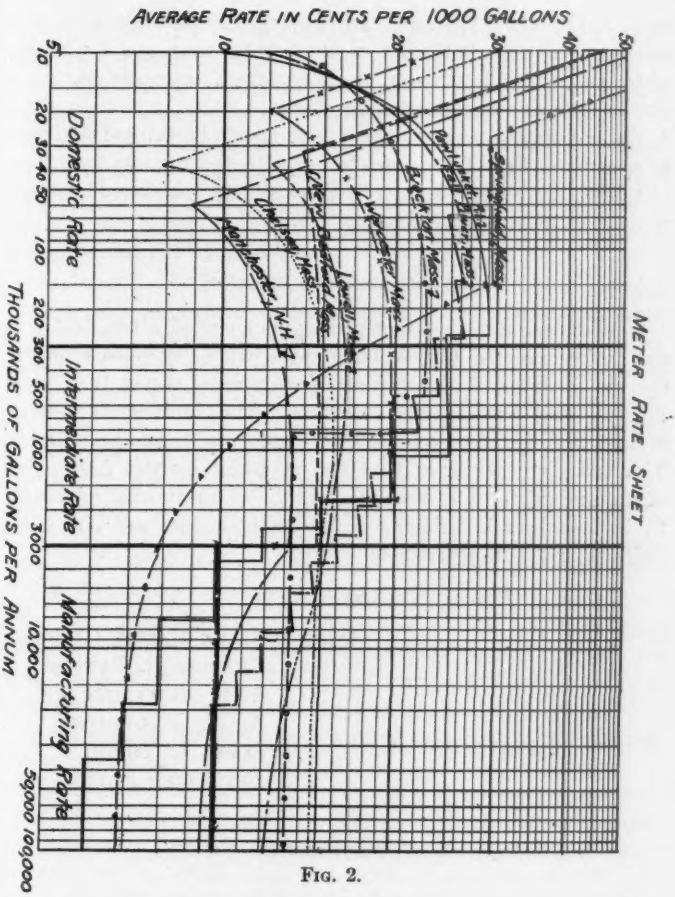

FIG. 2.

there is some point with a relatively small quantity of water, usually between 20 000 and 60 000 gal. per annum, where present rates are lower relatively than for either smaller or greater quantities. This point comes in most cases at the end of the minimum rate, that is to say, for a consumer that pays the minimum rate and draws the maximum quantity of water permitted under it.

Such consumers at present are paying substantially less with reference to the whole cost of the service than are consumers who take either less water or more water. Some of the rates now in force do not show this low point.

The committee suggests that blank sheets be printed and sent to every member of the Association with the request that rates of works in which he is interested be plotted and that blueprints of them be returned to the committee.

GRADUAL ADOPTION INTENDED.

It is undesirable that meter rates be changed often, and it is not to be expected that existing rates will be at once replaced. On the other hand, existing rates, even some of the best, have illogical and unreasonable features. The innumerable divergencies in forms of present rates are unfortunate and undesirable. The committee believes that the adoption by this Association of a standard form of schedule will be of substantial assistance to its members in bringing about methods that are both more uniform and more reasonable.

Respectfully,

(*Signed*) ALLEN HAZEN, *Chairman.*
CHARLES R. BETTES.
A. E. BLACKMER.
A. W. CUDDEBACK.
JAMES L. TIGHE.
PHILANDER BETTS.

DISCUSSION.

THE PRESIDENT. We have listened to another report of a kind that has given our Association its prestige, and, as Mr. Hazen has suggested, a free and full discussion is most desirable.

MR. J. M. DIVEN. Do I understand that with the sliding scale all consumers pay the same amount for the first 300 000 gal., whether they come under the manufacturer's rate or not?

MR. HAZEN. They do.

MR. DIVEN. Isn't the intermediate rate a little large? Doesn't that make a manufacturer pay first and second rates up to 10 000 gal. a day, which is as much water as an ordinary small factory would use? How is the intermediate rate arrived at?

MR. HAZEN. The intermediate rate is nearly midway between the domestic and manufacturing rate, and is determined by a fixed rule so that there can be no discussion as to what the intermediate rate should be after the others are arrived at, and it will always harmonize with the others.

MR. ARTHUR E. BLACKMER. There is one point that I would be very much interested in hearing the members discuss, and that is as to the value of water lost through the non-registration of meters. I think there was some difference of opinion among the members of the committee on that. The estimate of $2 in the report seems to me somewhat high, and I would be interested to hear what men who have had a good deal more experience than I in the care and handling of meters say on that question.

MR. DIVEN. It seems to me that is a pretty hard matter to determine. The only data we have is the loss in meters as they are tested. Of course, a meter when it is taken out and tested, after it has been in use for two years, would show a loss at that time which would not be a fair average of what it has been losing during its life. Probably when it was a new meter it lost very little. Possibly one way to arrive at it would be to take the new meter as showing no loss, and the tested meter after one or two years as, say, 10 per cent., or whatever it might be, and taking that as an average.

MR. HAZEN. Mr. Bettes, a member of the committee, engineer of the Queen's County Water Company, made some observations on meters and services and gave the committee results that were the basis for that part of the report. He found that no meter ordinarily, even a brand new one, would register less than 100 gal. per day. That is something for our meter men to discuss, and I would like to hear from them on that question. But if a meter will not register 100 gal. per day, and there should be a leak in the plumbing of any amount up to 100 gal. per day, then during all the part of the twenty-four hours when no other water is being drawn, the meter will give absolutely no record of it.

MR. ARTHUR A. REIMER. Those of us who are in the game directly handling meters must have found that 100 gal. per day is pretty well below the limit of a majority of meters. After handling several thousand meters I feel that the committee has not gone a bit too high in putting an average of 50 gal. per day for the leakage account, and I think they could safely go higher than that, if the experience we have had is any criterion. There is a difference in meters, as we all know, — surely in the different makes of meters, — and on comparing the specifications in different cities you will find that the leakage test, as it is called, varies anywhere from 10 gal. per hour to perhaps 20 or 25 gal. per hour. The meters are allowed a pretty large leeway even on that test, and a good many of them fall down.

Speaking to the first part of the report, I think that the committee is working along a very wise line in recommending that fewer steps be made in the sliding scale, wherever the sliding scale is used. Without throwing any bricks at anybody, I have been quite amused, to put it mildly, at the numerous steps in some sliding scales. I am not criticising any one, because the local conditions may have made it seem wise to adopt a many-step scale. But the clerical work involved in a scale with many steps must be very much greater than in the case of one, we will say, with three steps, such as the committee has advocated; and, furthermore, the adoption of a fairly high amount for the first step is in the right line, I think, also, because I should say that in 90 per cent. of the cities of the country we will find that the use in 75 per cent. of the individual cases will fall within that first step, thereby again decreasing the clerical work involved. I think that the committee is on the right line in that particular.

MR. R. C. P. COGGESHALL. Mr. President, I for one have felt that the unit should be the same to all takers. We had a very queer schedule of rates in our city a few years ago, and it was finally determined to make one rate flat, and the meter rate was established at 15 cents per thousand gallons. That obtained for over a year, everybody being satisfied, with the exception of the manufacturers. They came in and wanted lower rates, and finally the concession was made to them that for manufacturing purposes the rate should be 10 cents, and for everything else 15 cents.

That is the present established rate in New Bedford for the two units. So far as the registration is concerned, we call it 15 cents per thousand gallons, but all the bills are made out in cubic feet, at $1.12 per thousand cubic feet, or 75 cents, as the case may be. All the water that is used within a manufacturing enclosure we consider as used for manufacturing. We have now every service in New Bedford metered, and that produces a revenue which just about pays our expenses. I hope the time will come when we can put the meters in without making an extra charge for them, but we now make a rental charge. Mr. Whipple calls my attention to the fact that our dividing line is exactly the same as the committee has recommended.

Mr. G. F. Merrill. The question has been brought up as to whether it is customary, when several services are owned by the same property owner, to put those on the sliding scale. That is a matter which comes up sometimes with us.

The President. In Boston we oftentimes make an aggregate of all the water used within one enclosed area. For instance, if there is a fence surrounding half a dozen buildings, we would take the aggregate of the water used and apply the sliding scale. This report is of such unusual value that it would seem to me discussion might well be postponed until our November meeting.

Mr. William F. Sullivan. I move that the further discussion of the reports of the Committee on Statistics of Filter Operation and on Meter Rates be postponed until the November or December meeting, or until such time as the reports can be printed and copies be sent to all the members, so that we may get the benefit of written as well as oral discussion.

(Adopted.)

REPORT OF COMMITTEE ON STATISTICS OF WATER PURIFICATION PLANTS.

[*Read September 9, 1914.*]

To the Members of the New England Water Works Association:

On October 8, 1913, the undersigned were appointed as a committee to consider the subject of "Statistics of Water Purification Plants" and to recommend certain standard forms for reporting such statistics. Your committee has held several meetings and devoted considerable time to the subject, but is not ready at this date to make a final report, but merely a report of progress.

We have divided the subject into five topics. The present report deals with only the first two of these, and with these only in a preliminary way.

Believing that before any form of statistics is adopted it should be fully discussed by those most interested in the matter, we have prepared certain tabular forms for recording the results of analysis, which we beg to submit for discussion and criticism. We hope to be able to present a final report at the next annual meeting of the Association.

George C. Whipple, *Chairman.*
Robert Spurr Weston, *Secretary.*
F. D. West.
Frank W. Green.
E. E. Lockridge.

August 17, 1914.

REPORT OF COMMITTEE ON STATISTICS OF WATER PURIFICATION.

The studies which have been made by the committee may be considered under the following heads:

A. Descriptive data.
B. Statistics of analysis.
C. Engineering statistics.

NOTE.

This report will be open for discussion at a future meeting which will be announced later. All members having information pertaining to this subject, who are not able to attend this meeting, are urged to send it to the Editor for publication.

D. Financial statistics.

E. Vital statistics.

A. DESCRIPTIVE DATA. The number of water-purification plants in the United States to-day is very large, and during each year new plants are constructed. Descriptions of the most important plants have been published and may be found scattered through engineering papers, magazines, and official reports. When reading these, it is found that a number of important facts are omitted. So numerous are these omissions that it is impossible from the published descriptions to make compilations of even the most general data which will be adequate. Thinking that it would be of service to those preparing descriptions of filter plants for publication, the following schedule of desirable data has been prepared. Further details would be useful in many cases, but the following items in connection with the study of the operation of a purification plant are always important:

1. City or town, and population at last census.
2. Name of owner.
3. Name of designer.
4. Date when plant was put into service.
5. Total cost, with statement as to what is included.
6. Source of supply.
7. Rated capacity.
8. Method of purification.
9. Total capacity of subsiding or coagulating basins.
10. Total capacity of filtered water basin.
11. What chemicals are used.
12. Where chemicals are applied.
13. How applications of chemicals are made.
14. Number of filter units.
15. Net area of filter surface.
16. Depths of filtering materials.
17. Sizes of filtering materials.
18. For slow filters, — arrangements for cleaning sand surface, sand handling, sand washing.
19. For mechanical filters, — method of cleaning filter beds.
20. Number of subsiding or coagulating basins.
21. How the rate of filtration is controlled.

B. STATISTICS OF ANALYSIS. Through the efforts of the American Public Health Association, the methods of water analysis used in North America are now on a fairly uniform basis. The practice of expressing the results of chemical analysis in parts per million is almost universal and the methods employed are coming more and more into agreement.

Blanks have been prepared illustrating the committee's recommendations regarding the form of report, the tests to be made, and the method of expressing the results. These blanks are as follows:

Table 1. Chemical and Microscopical Character of Raw Water.
Table 2. Turbidity and Color of Raw Water.
Table 3. Bacteria in Raw Water.
Table 4. Chemical Character of Water Delivered to Mains.
Table 5. Turbidity and Color of Water Delivered to Mains.
Table 6. Numbers of Bacteria in Water Delivered to Mains.
Table 7. Numbers of B. Coli in Water Delivered to Mains.

All of the above tables are arranged to show the analytical data by months and years.

The elimination of unnecessary analytical work is a matter that needs consideration at this time quite as much as the making of the necessary tests. Laboratory practice at various purification plants has shown that many of the determinations which are ordinarily included in the standard water analysis schedule are here of little or no importance. For example, the determination of nitrogen in the usual forms of free and albuminoid ammonia, nitrites, and nitrates serves no particular purpose in water purification except in special cases. They neither assist the superintendent in the operation of the filter, nor give any adequate idea of the safety of the filtered water. On the other hand, some of the simpler physical tests, such as numerical determinations of turbidity, color, and odor, microscopical examinations and tests for alkalinity, iron, and carbonic acid, have come to be regarded as most valuable; and in special cases various other tests, such as dissolved oxygen and manganese. Bacteriological tests are of course important.

One step in making an analysis of water has never received half the attention that it deserves, namely, sampling. Of what value is it to use analytical methods of great refinement if the samples

themselves are not representative, if the mass of water from which the sample is taken is not homogeneous, or if the water changes in character from one day to another? Samples for chemical analyses are almost never larger than 4 liters (1 gal.); and samples for bacteriological analyses are seldom larger than 100 c.c. (4 oz.), while the quantities actually used for the different tests are still smaller. In counting the number of bacteria, the quantity used is less than a thimbleful.

On the other hand, we know that bodies of water are not homogeneous. In a lake or settling basin there are vertical and lateral variations; a river is constantly changing, not only in volume but in the character of the water; filter effluents vary, especially the effluents from mechanical filters where the runs are short and the rates are high. The causes of these variations which affect the results of water analyses through unfair sampling are so numerous that they cannot be studied by themselves, and the only course left is to apply to them the laws of probability, or, in other words, to arrange the data secured in some such way that the importance of the inevitable variations may be indicated and an index of the character of the water examined be obtained.

Thus we see that a question of fundamental importance is that of frequency of collecting samples. The question is, How often must samples be taken to obtain reliable results? As a general proposition it may be stated that the frequency of sampling should depend upon the frequency of change in the character of the water examined. For a water of constant quality, a few samples taken at infrequent intervals may serve to give a fair idea of the water, but if a water be subject to great fluctuations in character, a few samples taken at long intervals might or might not give a fair idea of the water. The reliability of the average result will be determined by the laws of probability. The average result does not tell the whole story, for it eliminates the individual results, and a water supply should be safe and wholesome all of the time.

The frequency of sampling has a limitation, which is controlled by practical and financial considerations. In a small plant the cost of daily analyses would usually be prohibitive, and even weekly analyses might be a burden. It would be recognized, however, that results based on infrequent samples are less valuable than

those based on frequent samples; and that irregular sampling gives the most unreliable results. In order to emphasize this point it seems desirable to establish certain grades of control of operation, based upon the character of the records kept, as follows:

First Grade: Water purification plants under first-grade supervision are those where analyses of the filtered water are made one or more times a day, and where engineering and such other data regarding the operation of the plant as are necessary are collected by one or more attendants constantly employed.

Second Grade: Water purification plants under second-grade supervision are those where analyses are made regularly, say once a week or once a month by a trained analyst, and where an attendant constantly on duty makes simple daily tests.

Third Grade: Filter plants under third-grade supervision are those where analyses are made irregularly and infrequently, and where no daily tests are made by the attendant.

Sometimes it is difficult to grade the supervision given a plant. As an example we have the Lawrence city filter, where daily tests are made during five winter and spring months of the year, and weekly tests during the remaining seven months. Here frequent analyses were made during those seasons which were most critical. This might be termed a mixed supervision of the first and second grades.

This grouping should not be considered as necessarily casting a stigma upon second- or third-grade supervision. Some water supplies may not demand first-grade records. In general it may be said that the safer the raw water, the lower may be the grade of analytical supervision. In other words, polluted waters require the purification plant to be operated with a higher factor of safety, and to this end a more careful analytical control is needed. Stored waters are safer than unstored waters, and with them a lower degree of analytical supervision may suffice. A corollary to this would be that small plants which cannot afford high-grade supervision of filters should endeavor to protect the quality of the supply by storage or by incorporating a large factor of safety in the design of the plant.

Explanation of the Terms Used.

Some explanation of the terms used in the various tables is necessary.

Test Day.

By the term " test day " is meant a period of twenty-four hours during which tests are made. This period of time seems to be the shortest period that it is practical to use as a statistical unit in determining the efficiency of water purification plants.

When more than one observation is made during a test day, the results should be combined by processes of averaging to obtain single numbers representative of the observations for that day. When this is done the fact should be so stated.

Bearing in mind that by the law of least squares the probable error of the result of a series of observations varies as the square root of the number of the observations, and assuming the precision of the results of daily sampling to be unity, then comparatively the precision of the results of weekly sampling would be only 0.38; that of monthly sampling, 0.18; and that of yearly sampling, 0.05; while the precision of hourly sampling would be 4.90.

Monthly and Annual Summaries.

For the purpose of uniform tabulation, calendar months and calendar years should be used as the basis of grouping the daily results.

Averages.

Each monthly average, or mean, should be obtained by dividing the sum of the daily results by the number of days on which tests were made during the month, that is, by the number of test days.

Strictly, the yearly average, or mean, should be obtained by dividing the sum of the daily results by the number of days on which tests were made during the year, that is, the yearly average should be the average for the twelve months weighted according to the number of test days in the month. When daily tests are made, however, this weighted average is practically the same as the simple average of the monthly results. When the number of test days in the different months varies, as in the case of a mixed record, the annual average thus computed does not give a fair

idea of the operation of the plant, as undue weight is given to those seasons when the largest number of tests are made. For this reason, and also for the sake of simplicity, the committee recommends that the annual average be taken as the mean of the twelve monthly averages.

Median.

The occurrence of occasional observations which are abnormally high often causes the average to be non-representative of the tests made during a month or year. Sometimes a single erratic test will greatly distort the average result. For this reason the median as well as the mean should be computed for each month and year.

Literally, the median is the result which lies in the middle of a series of results arranged in order from lowest to highest. That is, it is that value above and below which are an equal number of higher and lower values. For example, in the series 1, 2, 3, 8, 16, the figure 3 would be the median, while the average would be 6. To find the monthly median, arrange the daily results obtained during the month in order of magnitude. If there is an odd number of tests, select the middle term. If there is an even number, take as the median the average of the two middle terms. To find the yearly median, arrange the daily results for the entire year in order of magnitude, regardless of the month in which they occur. Do not take the average of the monthly median, or even the median of the monthly medians.

Further Statistical Analysis of Results.

The committee has considered the further analysis of the analytical data by the use of other statistical methods, but is of the opinion that these cannot be wisely adopted as standard procedures until further study of them has been made. The tables provide, however, for a classification of the data relative to turbidity, color, and number of bacteria into groups, from which further statistical studies may be made if desired. These need no special explanation.

Per Cent. of Time.

Several of the tables provide a horizontal line for the per cent. of time during which the results fall within the stated groups.

When lines are drawn through certain spaces in this and other summaries, they indicate that the spaces should not be filled out.

Precision of Analytical Methods.

Your committee has not concerned itself with methods of analysis, but recommends for the sake of uniformity that the Standard Methods of the American Public Health Association be adopted as far as practicable. Particular attention is called to the rules relating to the use of significant figures in recording the results of analyses. The following table is given for reference. The results of chemical analyses should be recorded preferably as parts per million.

Determination.	Results to be Reported.
Numbers of bacteria.	Ordinarily use two significant figures; never more than three.
Percentage of time.	To first decimal place.
Percentage of B. coli tests.	To nearest whole number.
Chlorine.	To first decimal place.
Hardness.	To nearest whole number.
Alkalinity.	To nearest whole number.
Carbon dioxide.	To nearest whole number.
Iron.	To second decimal place.
Oxygen consumed.	To first decimal place.
Manganese.	To second decimal place.

In general, averages of the above results should be carried out one decimal place beyond those mentioned, but in case the average is that of only a few items, this additional place is not necessary or desirable.

B. Coli Tests. In recording the results of tests for B. coli, it is recommended that when possible the words " Positive " and " Negative " be used, or their abbreviations, " Pos." or " Neg." If signs are used instead of words, it is suggested that the mathematical symbols plus (+) and minus (−) be used to indicate positive and negative results, and that when no test is made, the space shall be filled in with dots (....) and not a dash, which latter might be taken for a minus sign, or a zero, which might be taken for " no test."

The B. coli index is the approximate number of B. coli per c.c., as determined from qualitative tests made upon different quantities of water. For any individual sample, it may be taken as the reciprocal of the smallest volume of water used in the test which gave a positive result. Thus if a sample gave a positive test

with 0.1 c.c. and a negative test with 1.0 cc. and 10 c.c., the B. coli index would be $1 \div 0.1 = 10$. The B. coli index for a single sample is not very accurate. The index becomes more and more precise as the square root of the number of tests becomes larger.

The B. coli index may be computed from a series of results as follows:

Write down the percentages of positive tests for the given quantities examined, expressed as decimals of 100.

Take the differences between these percentages.

Multiply each of these differences by the reciprocal of the quantity corresponding to the larger of the two percentages from which such difference was taken.

The sum of these products will be the B. coli index.

For example, for the year April, 1912, to March, 1913, the records of the Metropolitan Water Board of London, England, show results as given in the first two columns below.

Quantity of Water Examined.	Per Cent. of Positive Tests.	Expressed as Decimals of 100.	Differences.	Reciprocals of Quantities.	Product.
100 c.c.	13.8	0.1380	.1090	.01	.00109
10 c.c.	2.9	0.0290	.0260	.1	.00260
1 c.c.	0.3	0.0030	.0026	1.0	.00260
0.1 c.c.	0.04	0.0004	.0003	10.0	.00300
0.01 c.c.	0.01	0.0001	.0001	100.0	.01000
0.001 c.c.	*			Index =	.01929

* No test, but assumed to be zero.

In the above example the B. coli index may be taken as 0.019, which would be equivalent to 19 B. coli per liter of water.

Efficiency of Operation. It will be noticed that no provision has been made in these tables for recording the percentage removal of bacteria, a method that has been much used in the past. Although this method has certain advantages, it is so susceptible to misuse that the committee recommends that it be omitted from official reports of filter operation.

Reasons why the "Percentage Removal" Method is Unsatisfactory. The common method of judging the efficiency of a water filtration plant by means of the percentage removal of bacteria is unsatisfactory for several reasons.

ERRATA.

Report of Committee on Statistics of Water Purification Plants.

Journal N. E. W. W. Association, Vol. 28.

On page 227, the next to last word should be "negative" and not "positive," and on page 228 the word "negative" should be changed to "positive," so that the sentence beginning at the bottom of page 227 should read:

Thus if a sample gave a negative test with 0.1 cc. and a positive test with 1.0 cc. and 10 cc., the B. coli index would be $1 \div 0.1 = 10$.

(1) The bacteria found in the effluent are not all derived from the raw water. A certain and varying number of them represent growths in the lower part of the filter. The bacteria from this source do not vary in number with the number of bacteria in the raw water, but with the rate of filtration, with disturbances occasioned by the collection of air within the filter, and with other factors of operation.

(2) It requires a certain time for the water to pass from the point where the raw water sample is taken to the point where the filtered-water sample is taken. Sometimes this amounts to several hours, and in the case of a water which changes rapidly in quality and character it is necessary to make an allowance for this time if a correct comparison is to be obtained. As a matter of convenience it is common to collect samples of the raw and filtered water at about the same time. Hence there may be an error due to this difference in phase. Whether or not this is of importance depends upon the uniformity in the character of the raw water.

(3) The percentage removal is to a certain extent a function of the number of bacteria in the raw water. It is a well-known fact that the percentage removal of bacteria is relatively high when the raw water contains large numbers of bacteria and relatively low when the raw water contains few bacteria. One reason for this is because the bacteria which develop within the filter are a smaller proportion of the total number of bacteria in the effluent when the number of bacteria passing through the filter is large.

(4) The percentage removed does not necessarily vary with the number of bacteria left in the filtered water. The following is an example:

Day.	Numbers of Bacteria.		Percentage Removed.
	Raw Water.	Filter Effluent.	
1st	50	3	90.4
2d	1 000	10	99.0
3d	600	20	96.6
Average	555	11	

It will be noted that on the day when the number of bacteria in the effluent was lowest, the efficiency as shown by the percentage removal was also lowest.

(5) The infectiousness of a water does not necessarily vary with the number of bacteria in the water, but in most waters there will doubtless be some connection between the two. A water polluted with surface wash would doubtless increase in infectiousness, and the numbers of bacteria would increase with increased stream flow. On the other hand, a water regularly polluted with sewage, other things being equal, would increase in infectiousness as stream flow decreased, that is, as dilution became less, while the numbers of bacteria under these conditions might decrease. Hence, there seems to be no very definite relation between the infectiousness of a filtered water and the percentage removed of bacteria by a purification plant, which percentage varies according to the numbers of bacteria in the raw water.

(6) If any comparison is to be made between the numbers of bacteria in the raw and filtered waters it would be better to use the "percentage of bacteria remaining," partly because the numbers themselves are smaller and easier to handle, and partly because the figures show to better advantage the variations in the operation of the filter; for example, when two filters, with the same raw water, are operating so as to produce 98 and 99 per cent. "removals" of bacteria respectively, the numbers of bacteria remaining in the effluent of the first will be twice as many as in the effluent of the second. Again, comparing one filter with an efficiency of 99 per cent. with another filter with an efficiency of 99.9 per cent., both operating with the same raw water, the difference at first sight seems small, yet the effluent of the first of these filters contains ten times as many bacteria as the effluent of the second. Hence, the method of stating efficiency of a filter plant in terms of "bacterial removal" may be misleading.

(7) A single figure showing the percentage removal of bacteria during a certain time — as, for example, a month — gives no idea of the regularity of operation of the filter during this period. For example, in the illustration above mentioned the percentage of bacteria remaining in the effluent varied on different days from 1.0 per cent. to 9.6 per cent. of the number of bacteria in the raw

water, while the average of the per cents. remaining was 3.7 per cent. and the median 3.4 per cent.

(8) A common fault of filter specifications is the provision that the plant shall show a certain percentage removal of bacteria when the numbers of bacteria in the raw water are below a certain limit. This specification is inadequate. A good water-purification plant is one which produces a satisfactory effluent every day of the year and every hour of the day; and, if efficiency can be expressed on a percentage basis, it should be indicated by the percentage of the time during which the plant produced a good effluent, rather than by the percentage comparison of bacteria in influent and effluent respectively.

TABLE 1.—CHEMICAL AND MICROSCOPICAL CHARACTER OF (RAW) WATER.
For the Year ———.
(Parts per 1 000 000.)

Month.	Chlorine.	Total Hardness.	Permanent Hardness.	Alkalinity.			Free CO_2		Dissolved Oxygen.	Iron.	Suspended Matter.	Oxygen Consumed.	Micro-Organisms.	Remarks.
				Av.	Max.	Min.	Av.	Max.					Std. Units per c.c.*	
Jan. ↓ Dec.														
Average														

* Use standard units; if numbers are used, so state.
[Raw] Water to be designated by name of source, e. g., "Hudson River," "Wells," "Lake George."

TABLE 2.—TURBIDITY AND COLOR OF ( ) WATER.
For the Year ———.
(Parts per 1 000 000.)

Month.	No. of Test Days.	Mean Turbidity.	Turbidity. Variations: No. of Test Days.							No. of Test Days.	Mean Color.	Color. Variations: No. of Test Days.				
			0–10.	11–25.	26–50.	51–100.	101–250.	251–500	Above 500.			0–10.	11–25.	21–50.	51–100.	Above 100.
Jan. ↓ Dec.																
Total																
Average																
% Time																

TABLE 3.—BACTERIA IN ( ) WATER.

For the Year ———.

Month.	No. of Bacteria on Gelatine at 20 Degrees C.									Bacillus Coli.									B. Coli Index.
	No. of Test Days.	Mean per c.c.	Median per c.c.	Variations in Numbers: No. of Test Days.						No. of Test Days.	0.01 c.c. Tests.			0.1 c.c. Tests.			1.0 c.c. Tests.			
				0–100.	100–300.	300–1 000.	100–10 000.	10 000–100 000.	Above 100 000.		Total No.	+ No.	Per cent. +	Total No.	+ No.	Per cent. +	Total No.	+ No.	Per cent. +	Number per c.c.
Jan. ↓ Dec.																				
Total																				
Average																				
Per cent. time																				

TABLE 4.—CHEMICAL CHARACTER OF WATER DELIVERED TO MAINS.

For the Year ———.

(Parts per 1 000 000.)

Month.	Chlorine.	Total Hardness.	Permanent Hardness.	Alkalinity.		Free CO_2.		Iron.	Oxygen Consumed.
				Average.	Minimum.	Average.	Maximum.		
Jan. ↓ Dec.									
Average									

TABLE 5.—TURBIDITY AND COLOR OF WATER DELIVERED TO MAINS.
For the Year ———.
(Parts per 1 000 000.)

Month.	Turbidity.						Color.				
	No. of Test Days.	Mean Turbidity.	Variation in Turbidity: Number of Test Days.				No. of Test Days.	Mean Color.	Variations in Color: Number of Test Days.		
			0.	1–5.	6–10.	Above 10.			0–5.	6–10.	Above 10.
Jan. ↓ Dec.											
Total											
Average.											
Per cent. time											

TABLE 6.—NUMBERS OF BACTERIA IN WATER DELIVERED TO MAINS.
For the Year ———.

Month.	On Gelatine at 20 Degrees C.									On Agar at 37.5 Degrees C.							
	No. of Test Days.	Mean per c.c.	Median per c.c.	Variations in Numbers: No. of Test Days.						No. of Test Days.	Mean per c.c.	Median per c.c.	Range of Counts.				
				0–10.	11–25.	26–50.	51–100.	101–250.	Above 250.				0–10.	11–25.	36–50.	51–100.	Above 100.
Jan. ↓ Dec.																	
Total																	
Average																	
Per cent. time																	

TABLE 7. — Numbers of Bacilli Coli in Water Delivered to Mains.

For the Year ——.

Month.	Bacillus Coli.							B. Coli Index.	Remarks.
	No. of Test Days.	One c.c. Tests.			Ten c.c. Tests.			Number per c.c.	
		Total No.	No. +	Per cent. +	Total No.	No. +	Per cent. +		
Jan. ↓ Dec.									
Total									
Average									
Per cent. time									

DISCUSSION.

MR. EDWIN C. BROOKS. Mr. Whipple has given us an excellent test for finding dirt or algæ in a sample of water. The Cambridge water supply pipes have been in years past galvanized iron pipes, and we all know that they fur up very rapidly, and that the interior becomes very rough. The question arises whether, unless a sufficient amount of water is drawn through the pipe to thoroughly wash it out, you will get a fair sample of the water in the main.

MR. ROBERT S. WESTON. I have collected a number of cotton sediment records from different parts of New England. There is a series taken since the 16th of August from the Metropolitan water-works tap at 14 Beacon Street, and you see there is a great variation in cleanness. On the 25th of August the water was quite dark in color, that is, the sediment was quite dark, but in a majority of cases the water is fairly clean. Also there are a number of tests made with Brookline water. The Brookline water, as you know, contains iron. Sometimes the iron settles out in the mains, and sometimes the iron rust becomes evident at the taps. There are also tests of samples from the experimental filter which Mr. Forbes is running, showing the sediment in the raw water and in the water from the settling basin and the absence of sediment from the filtered water. There are some samples from Belfast, Me., and other places.

Perhaps Professor Whipple didn't say that the committee hopes to be able to continue its work and to take up among other things the question of the effect of filter operations upon the vital statistics. It has been stated by a great many people that water filters, especially mechanical filters, are efficient, and by some others that they are not, and it seems a good time for the committee to get some facts as to the real hygienic value of these devices, with the hope of advancing the subject beyond the controversial stage.

The financial statistics of water purification plants are also in a rather chaotic condition, and the committee hopes to be able to make some contribution along this line. For instance, the cost of operation without depreciation and without interest is

often compared with the cost of operation with these fixed charges included, and the cost of operation very often includes such items as " care of grounds," etc.

The committee also hopes to acquire copies of the records from the various water purification plants, and desires the operators of such plants to coöperate with it in getting such operation data recorded on the standard forms. A few plants are furnishing very good records, but no two records are on the same basis.

THE NEW WATER PURIFICATION PLANT AT MIRAFLORES, CANAL ZONE.

BY GEORGE M. WELLS, DIVISION ENGINEER.

[*Read September 10, 1914.*]

As an introduction to a paper descriptive of the New Water Purification Plant, now in course of construction by the United States Government near the Miraflores locks, it has occurred to the writer that a brief outline of the conditions from which resulted the decision to adopt an entirely new project for the water supply for the southern end of the Panama Canal might prove of interest to the members of the New England Water Works Association.

The water supply for all points in the canal south of the Culebra Cut, including the towns of Paraiso, Pedro Miguel, Corozal, Ancon, Balboa, and the city of Panama, was obtained, prior to October, 1913, in part from the Rio Grande reservoir by gravity, and in part from the Cocoli lake by pumping.

The Rio Grande reservoir is located on a river of the same name, about eleven miles distant from the city of Panama, and along the old line of the Panama Railroad on the west side of the canal. A 16-in. cast-iron main laid in 1905 and a 20-in. cast-iron main laid in 1912 carried the water from the reservoir through the first four towns above mentioned to Panama City and Balboa. At the west side and north end of the Pedro Miguel locks these mains were combined into a single 24-in. main, which was laid in the masonry floor and side walls and extended to the east side, where the 16-in. and 20-in. mains continued along the line of the Panama Railroad for the remainder of their length.

Early in 1910 the consumption of water had risen to over 3 500 000 gal. per day, and it became necessary to supplement this amount by pumping from the Cocoli River, as the Rio Grande reservoir could not be relied upon to furnish much in excess of that amount during months of minimum rainfall. Temporary

electric-driven pumps were installed on the Cocoli, a river lying on the west side of the canal, opposite Miraflores. Temporary pipe lines were laid from these pumps across the Miraflores locks and connected in to the 16-in. and 20-in. mains from Rio Grande.

The watershed of the Rio Grande reservoir is uninhabited, and is rigidly kept free from all trespassing. This was also more or less true of the Cocoli watershed, and the water from these sources was practically above suspicion as far as pollution from human beings was concerned. The water, however, was objectionable from the standpoint of iron content, color, and odor, and a certain amount of purification was obtained by pumping that portion of the supply reaching Panama City through pressure filters, Continental Jewell type, without sedimentation.

By 1913 the consumption had risen to 7 500 000 gal. per day, thus taxing both the Rio Grande and Cocoli supply to the utmost. The approaching completion of the Miraflores locks and the creation of the Miraflores lake resulted in the flooding of the lower part of the Cocoli valley, and consequently eliminated this part of the supply, necessitating the moving of the pumps to the east side of the canal, where they were installed for pumping water into the 16-in. and 20-in. mains from the newly created lake, as a supplementary supply.

By reason of the territory flooded and also by reason of the sewage emptying into the lake from the town of Pedro Miguel, located at the northern end, the water is more or less polluted. A hypochlorite dosing plant was therefore installed, and from 8 to 11 lb. of bleach per million gallons is being applied to all water passing south of Pedro Miguel.

The more or less inadequate and unsatisfactory water supply was the subject of considerable study as far back as the early part of 1912, and in March, 1913, a committee, of which the writer was a member, was convened to report on and recommend an entirely new project for the permanent water supply for the southern end of the Panama Canal. After several months of study, during which time five different projects were worked up, including estimates of costs, the project now under construction was submitted by the writer and approved by the chairman and chief engineer.

This project involved the abandonment of the Rio Grande supply and the taking of all water from an arm of the Miraflores lake lying east of the Panama Railroad and just north of the railroad tunnel; the construction of a raw-water pumping station at the edge of the lake; the purification of the water by aëration, sedimentation, filtration, and hypochlorite treatment; the laying of a new 30-in. cast-iron main from Miraflores to Ancon; the construction of a booster pumping station at Ancon; the enlargement of the existing 1 000 000-gal. reservoir on the side of Ancon Hill to 2 500 000 gal. capacity; the laying of a new 16-in. cast-iron main from the booster station to this reservoir, and the laying of the necessary new 20-in. and 16-in. lines between this pump station and the city of Panama, the canal terminals, and permanent towns.

The results of the various studies and the many reasons leading to the adoption of the project as outlined will not be taken up in this paper. Suffice it to state, however, that the necessity for meeting the increasing water demands; the requirement that existing pumping stations and pipe lines should be moved or changed as the canal construction demanded without interruption to the supply; that any new plant proposed should provide for either low or high-pressure service through a single distributing system, extending from practically sea level to nearly 200 ft. above; the necessity of using Miraflores lake water, which is, and always will be, more or less polluted; the requirement that the water furnished should be above suspicion and free from odors, taste, color, iron, and all organic matter; and finally the natural topographical difficulties to be overcome, — all combined to present a most interesting problem, not only from the standpoint of design but from the standpoint of first cost and economy of operation as well.

The purification plant is located at the extreme westerly end and on the crest of the ridge, which extends with precipitous sides from the high hills lying east of the Panama Railroad tunnel at Miraflores to the spillway at the north end of the locks. This places the filter building end of the plant almost immediately above the east abutment of the spillway. The finished ground elevation around the buildings has been fixed at 116 ft. above

sea level, or approximately 61 ft. above the normal level of the water in Miraflores lake.

The plant as designed provides for a nominal maximum capacity at a 125 000 000-gal. per acre rate of 12 000 000 gal. per day, and an extreme maximum capacity at this rate of 15 000 000 gal. per day, exclusive of wash water and with one filter out of service.

The raw water will be delivered to the aëration basin through a 30-in. cast-iron main from the so-called raw-water pumping station located, as stated, on the arm of the Miraflores lake lying east of the Panama Railroad. Falling to the floor of the aëration basin the water will pass into the basement of the head house over shallow weirs. At these weirs it will receive a dose of aluminum sulphate, and will then pass through a series of mixing chambers into the sedimentation basin. This basin, which will be the continuous type, will provide from five to eight hours of sedimentation. Passing out of the sedimentation basin the water will flow to 14 filters through two 30-in. distributing pipes, and from the filters will pass through specially designed controllers through the floor of the pipe gallery directly into a clear water basin extending over the entire area beneath the filter beds. From this basin the water will flow through a 30-in. main to an injection and mixing chamber located approximately 150 ft. distant from and about 25 ft. lower than the floor of the clear water basin. In this chamber will be applied a dose of hypochlorite of lime, and after passing through a series of baffles the water will finally enter the cast-iron mains leading to the Ancon booster pumping station located approximately five miles to the south.

Water for washing filters, for service around the plant, and for supplying the town of Pedro Miguel, located about two miles to the north, will be furnished by pumps placed in a second station, known as United States Pumping Station No. 2, and located near the injection chamber. This station will deliver the water from the mains to a 300 000 gal. capacity concrete tank located on the ridge to the east of the main plant and at an elevation of approximately 200. The wash water will be delivered from this tank to the filters through a 20-in. cast-iron main, and the general service water will be carried to the plant through a separate 4-in. cast-iron line.

For sake of clearness and convenience, a detailed description of the different units of the plant will be taken up in the following order: Aëration Basin; Head House and Mixing Chambers; Sedimentation Basin; Filter Building; Injection Chamber; Effluent Controllers; Alum and Hypochlorite Mixing Apparatus, and Hypochlorite Dosing Apparatus.

AËRATION BASIN.

All ground waters on the Isthmus of Panama, at least all within the Canal Zone, when allowed to stand in reservoirs or pipes, at times give off objectionable odors when discharged. These odors result from the hydrogen sulphide gas given off by the large quantities of decomposing vegetable matter present in the raw water. Aside from being acutely disagreeable to the sense of smell, this gas attacks all paints in the immediate vicinity having lead or zinc bases, and also discolors metals. The odor given off by the Gatun Lake water as it flows over the spillway at times reaches such volume and strength as to be plainly noticeable down the wind for a distance of nearly two miles. It is obvious that in the treatment of water of such character more or less elaborate aëration seems warranted.

The iron content in the water of the Miraflores lake generally runs from .8 to 2.5 parts per million. This iron is in solution, and experiments conducted, using compressed air at low pressure and considerable volume, indicated that aëration might be expected to prove of valuable assistance as a preliminary treatment to the application of sulphate of aluminum. The changing of the iron from the ferrous to the ferric state during aëration and its partial elimination by precipitation in the aëration basin seemed to result — at least in the case of the water passing the Gatun purification plant at Agua Clara — in an appreciable reduction in the amount of aluminum sulphate required to remove the color. This becomes a vital point in waters of low alkalinity and high color, and the writer in designing the new plant for Colon and Cristobal attempted a more or less elaborate aëration system. This plant is just going into operation, and definite data on results are therefore not available at this time.

For similar reasons, although the iron content in the Miraflores water is a little lower than in the Colon water, the aëration basin becomes an important part of the Miraflores plant.

This basin, as designed, will be a reinforced concrete structure, rectangular in plan, 86 ft. wide by 125 ft. long, inside wall dimensions. The floor will be flat, resting throughout its area directly on clay foundation, and will have a thickness of approximately 6 in. The side walls, 6 in. in thickness, will extend 6 ft. above the floor, and are merely to prevent the waste of water that would result from the striking of the spray on the concrete floor after falling from a height of 15 to 20 ft. The elevation of the floor has been fixed at 126.

The 30-in. main from the raw-water station will extend the full length of the north side of the basin and will be outside the wall, distant therefrom about 4.5 ft., and below the floor level approximately 2.5 ft. From the top of this 30-in. pipe will be taken off seven 12-in. diameter pipes spaced at intervals of 16 ft. Each of these pipes will lead horizontally through the side wall on to the floor of the basin, and at a point 15 ft. inside will split into two 8-in. pipes, which will form a loop extending across the basin. The pipes when assembled will present the appearance of a grid of fourteen 8-in. pipes, with each pair cross-connected at the southerly side of the basin and fed by a single 12-in. line at the opposite side.

At intervals of 8 ft. on the 8-in. pipe will be located 4-in. outlets extending vertically upward. These outlets will be staggered in such a way as to cause them to be located in triangular plan. To each of these outlets will be located the bronze aëration nozzle. There will thus be a total of 105 nozzles.

The nozzle adopted will consist of a special flanged outlet within which will fit a bronze truncated cone having a face angle of 20° inclination from the vertical. The diameter of the outlet will be $3\frac{3}{8}$ in., but the maximum opening between the lip of the outlet and the face of the cone will not exceed $\frac{3}{16}$ in. measured perpendicular to the cone for maximum required discharge. The cone will be held in place by an adjustable bronze bolt extending into a cross rib located just above the plane of the flanges connecting the nozzle to the 4-in. outlet from the 8-in. feed pipe.

The design of these nozzles was determined upon after experiments with nozzles of different types and by full sized tests had shown the character, volume, and shape of the spray delivered under varying heads.

Under operating conditions it is expected that the water from these nozzles will be thrown from 15 to 20 ft. into the air, and the tests showed that the water was broken from a thin sheet into coarse drops about two thirds of the distance up, changing to spray at the top of the rise and falling as such to the basin floor.

Each nozzle at full pressure will deliver approximately 200 000 gal. per day, but the opening is so designed that when delivering 50 per cent. of this amount at a low pressure, satisfactory breaking up of the water may be expected.

Outside the basin wall, in each 12-in. feed pipe, will be located two valves, one hand-operated and one hydraulically operated. The piping from the latter valves will lead to controllers located in a float box in the head house. This box will be connected by a 12-in. pipe to the receiving chamber at the entrance to the filter building, and the water level rising or falling in this box simultaneously with the level in the receiving chamber will actuate floats carrying stems to small piston valves, which will open or close the hydraulic valves at the aëration basin, cutting out or in the various banks of nozzles according as the throwing in or out of filters increases or decreases the draft on the sedimentation basin. By this means the quantity of water admitted to the aëration basin will be automatically regulated to meet the more or less constantly varying outflow to the clear-water basin, resulting from throwing filters in and out of service.

The float controller for the hydraulic valves will consist of a bronze shell, within which will be placed a cylindrical piston attached by a vertical stem to a copper float resting on the surface of the water in the float box. The shell has been so designed that the feed water for operating the hydraulic cylinders on the valves will pass into it through ports, and, according to position of the piston, will flow to the top or bottom side of the valve cylinder, under pressure. The water from the opposite side of the hydraulic valve piston will escape through a waste port in the shell. In short, the controller is a simple adaptation of a cylinder and piston

valve for accomplishment through float movement of the same result obtained by the ordinary hand-operated four-way valve. The hand-operated 12-in. valves referred to are to be operated only at times when the occasion may arise to remove or repair the hydraulic valves.

The water will pass from the aëration basin to the mixing chambers in the head house over three weirs 12 in. deep by 15 ft. in length, which will be simple slots in the back wall of the head house. These weirs will have their crests at such an elevation that for maximum flow the depth of water on the floor of the aëration basin will not exceed 9 in.

HEAD HOUSE AND MIXING CHAMBERS.

The head house will be a reinforced concrete building, approximately 38.5 ft. wide by 92 ft. in length, and three stories in height. It will be located between the aëration basin and the sedimentation basin, and the lower portion of its side walls will form the east and west end walls of the sedimentation and aëration basins respectively.

The bottom story or basement will contain three separate mixing chambers, each 15 ft. in width and extending across the building from the aëration basin weir to the entrance weirs to the sedimentation basin. The layout of under drainage piping and valves for removing sludge will also be located on this floor. At the southern end of the building will be located the freight elevator, running from the basement to the third floor. On the basement floor and at this end of the building will also be located lavatories, shower baths, lockers for the colored employees, transformer room, and room for the elevator machinery and motors. At the opposite end of the building, the main entrance end, placed between the floor of the basement and the second floor, will be located the float box above described in connection with the aëration basin. This will appear depressed below the floor level on each side of the main entrance as one enters to the secomd floor.

The walls of the mixing chamber will rise to the level of the second floor, and here will be located the constant head float boxes and apparatus for measuring and applying the aluminum sulphate to the water as it passes into the mixing chambers from

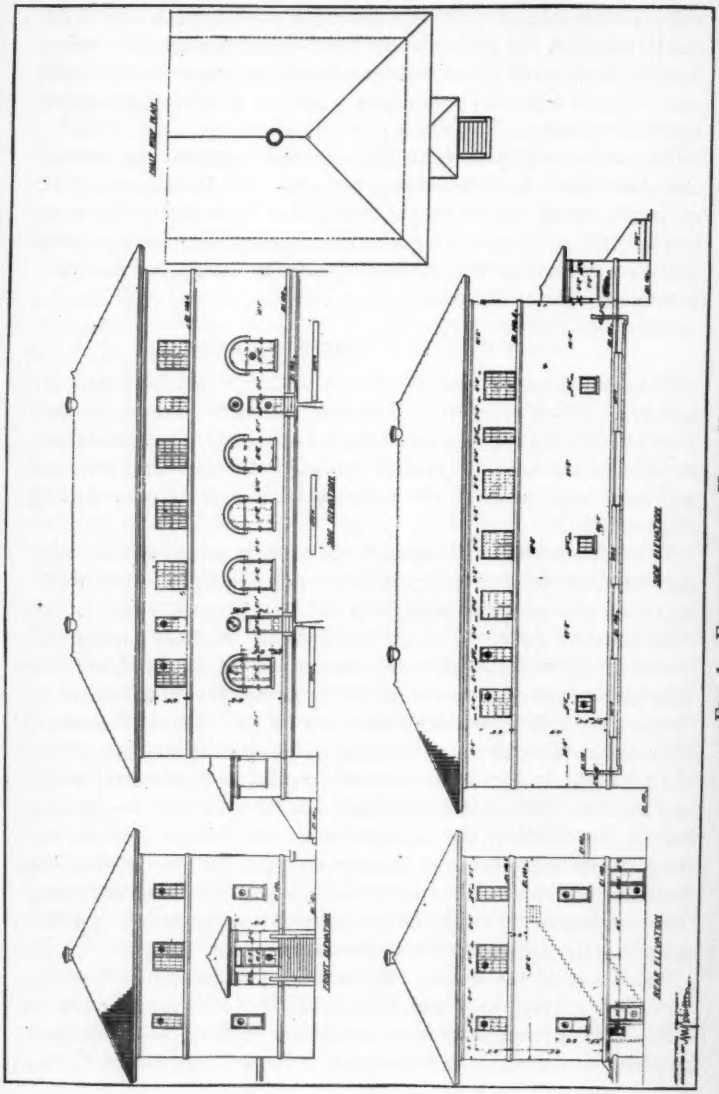

FIG. 1. ELEVATIONS OF HEAD HOUSE.

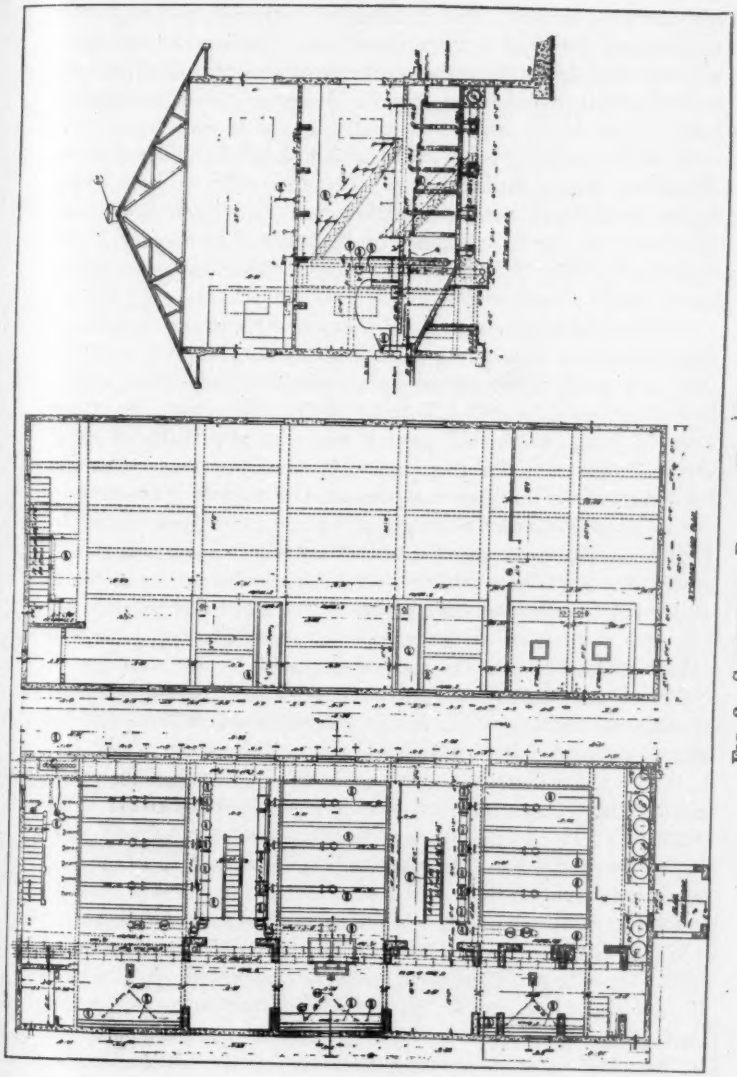

FIG. 2. SECTION AND PLAN OF HEAD HOUSE.

the aëration chamber. From this floor access will be had to the walks along the tops of the sedimentation basin walls, and here will also be located the slate operating table from which will be controlled the hydraulic valves for draining the sedimentation basin.

The third floor will carry two aluminum sulphate and two hypochlorite of lime solution tanks. The alum tanks will be 12 ft. square by 9 ft. in depth, with their walls reaching about 1.25 ft. above the floor level and 7.75 ft. below. The hypochlorite tanks will be 8 ft. by 12 ft. by 9 ft. deep, with walls also extending above and below floor level.

The hypochlorite room will be provided by running a concrete partition across the building about 21 ft. from the north end and just clear of the hypochlorite tanks. This will give floor space, including tops of tanks, of 21 ft. by 37 ft. The remainder of the floor, 37 ft. by 69 ft., will provide space for about nine months' alum storage. The alum and hypochlorite will be delivered to the south face of the building in wagons and lifted to the storage floor by an electric-driven platform elevator. Air-driven traveling triplex blocks, running on I-beams hung to the lower side of the roof trusses, will provide for ready and convenient handling of material from elevator to storage. Separate trolley blocks will run over the tops of alum tanks, for the easy placing of the aluminum sulphate on to the dissolving screens.

The mixing chambers will be concrete boxes approximately 37 ft. long by 15 ft. by 8 ft. deep. Each chamber will be divided transversely by 6-in. walls into eight compartments. One half of these walls will extend to within 6 in. of the bottom of the chamber forming submerged weirs, and the tops of the remainder of the walls will form over-fall weirs, with the elevation of each weir beginning at the aëration basin end $4\frac{1}{2}$ in. higher than the next succeeding one.

Extending along the edges of the submerged weirs will be placed $1\frac{1}{2}$-in. pipes having $\frac{1}{8}$-in. diameter holes spaced 6 in. centers, drilled in the lower half. Through these pipes compressed air at a pressure of about 5 lb. per sq. in. will be admitted into the chamber during operation.

The water entering the first compartment of the mixing chamber,

from the weir placed in the main wall, will pass under aluminum sulphate solution injection pipes and, receiving its proper dose of chemical, will flow vertically down and through the first submerged weir. In passing this weir the water will pass through jets of compressed air, and rising to the top of the second compartment will pass over the first over-fall weir to the third compartment. In this manner, the water will flow over and under successive weirs to the sedimentation basin. It is estimated that the water will be, under full operating conditions, five minutes in passing through these mixing chambers, and that this will provide ample time for thorough mixing and the complete formation of floc before reaching the first section of the sedimentation basin.

These mixing chambers are in no way connected with each other, and correspond with the three main divisions of the sedimentation basin. In the event of two thirds or all of the sedimentation basin being in operation, the entry weirs at the aëration basin, placed as they will be at the same elevation, will split the flow into two or three equal parts as the case may be. With the entire plant in operation, there will in effect be three mixing chambers and three sedimentation basins working simultaneously in parallel, each delivering its one third of the total to the filter building. This arrangement allows one or more divisions to be thrown out of service and cleaned, as desired, without interference with the operation of the remaining divisions. With the exception of a small area at one end of the mixing chambers, the water is visible to the operator throughout its course to the sedimentation basin, and the condition of the water as affected by the chemical may be under constant observation.

Eight in. and 10-in. cast-iron sludge pipes connect the bottom of each compartment with the main outfall sewer, and the valves controlling these lines will be located on the floor of the basement, reached either from the second floor by stairs or from the basement gallery running the full length of the building next to the aëration basin wall.

SEDIMENTATION BASIN.

The sedimentation basin will extend from the face of the head house wall to the east wall of the filter building. It will be of

reinforced concrete, rectangular in plan, with dimensions, center to center of outside walls, 125 ft. by 300 ft. The depth at the floor valleys will be 17.75 ft., and at the summits, 16.5 ft. Its capacity will be approximately 4 500 000 gal. The floor will be located about 7 ft. below the finished ground level and the walls will thus have 9.5 ft. of face above.

The basin will be divided longitudinally into three main divisions by pressure walls. Each of these divisions will be operated entirely separate from or in conjunction with either or both of the other divisions. They will be divided transversely into three compartments by two pressure walls. The first and second compartments will be divided into three sections by two light baffle walls running across the compartment. These baffle walls will be solid for a distance of three feet up from the bottom, and above this they will be pierced with as large openings and as many as practicable, reaching to within 2.5 ft. of the top. The remaining height of wall will be solid. The third compartment next to the filter building will be divided into two sections by one baffle wall only, built in the same manner as described for the first and second compartments.

The floor of the first two compartments will slope 1 in 12 from each baffle and transverse pressure wall to center valleys running transversely across the basin. In each of these compartments there will thus be three valleys. In the third compartment the floor will slope 1 in 20 to two central valleys.

The under-drainage system will consist of 20-in. cast-iron leadite jointed pipe, laid in solid concrete about two feet below the floor at the valleys. One 20-in. pipe line will be placed at each valley and will extend through to a main discharge sludge culvert, running parallel to the outside wall on the south side of the basin and located about six feet distant from the wall face.

In each section of a compartment will be located two 16-in. diameter outlets leading into the 20-in. under drain. These outlets will be located at about the quarter points in the valleys.

The sludge culvert will be built of reinforced concrete, and will be 3 ft. by 3.75 ft. in cross section, and the 20-in. under drains will have their outlets in the side walls of this culvert. Near the filter building end of the basin the culvert will end in a 24-in. cast-

iron pipe, laid in concrete, extending down the hill to the south to elevation about 100, and there reducing to 20-in. diameter, it will follow the hill around the westerly end of the filter building until it passes the abutment of the spillway, and then drop directly to lake level at elevation 55. With the elevation of the water in the sedimentation basin at 125 and the outlet of the 20-in. discharge pipe at 55, it is expected that the compartments will be largely self-cleaning.

Each 20-in. under drain will be controlled by a 20-in. hydraulically operated gate valve located in a covered gallery just above and between the discharge culvert and the outside of the southerly wall. On the wall of this gallery will be carried the control piping for the valves. This piping will end in a slate operating table, of the filter table type, that will be located on the second floor of the head house. The emptying of any compartment or division will therefore be controlled from one point in the head house where the operator will have a clear view over the entire basin.

The treated water as it falls from the last weir in the mixing chamber will pass into the first compartment through one port or submerged weir, 1.5 ft. wide by 15 ft. long, located in the wall 3.5 ft. below the normal water level. The path of the water will then be through the large submerged ports in the baffle wall to the pressure wall separating the first and second compartments. This wall will be pierced with five ports, placed about 3.5 ft. below water level and extending throughout its length. Each port will be 1.5 ft. wide by 6 ft. long. In front of these ports will be placed a thin concrete wall supported on a floor or shelf extending out from the main wall at a point just below the bottom of the ports. This wall will extend to within a foot of the surface of the water and thus form a skimming weir extending the entire width of the compartment. The water will thus pass over this weir and then down through the ports into the second compartment. This arrangement of ports and skimming weir is repeated in the second pressure wall, and the water finally reaches the receiving box, located between the end wall of the basin and the wall of the filter building, by passing over a third weir of somewhat different construction from the skimming weirs.

In the tops of the two main pressure walls extending longi-

tudinally through the basin, separating it into the three divisions, and at the head house end, will be placed weirs with flashboards for cross filling purposes.

For the purpose of illustrating the operation of these weirs, let us assume two adjacent divisions of the basin in operation, together with the two corresponding mixing chambers. The flashboard on the weir at the aëration basin, leading into the third mixing chamber, is down, and this chamber, together with the third division of the sedimentation basin, is empty and cleaned, ready for filling with treated water preparatory to throwing into service. Let us further assume that the filters are running at full capacity of 15 000 000 gal. per day.

The flashboards on the cross filling weirs are first lifted, thus allowing an overflow from the two operating divisions into the empty division. The flashboard on the third weir at the aëration basin is also lifted. The level of the water in the receiving box at the filter building drops, due to the drop of level over that portion of the basin in operation. This lowers the level of the water in the controller box located in the head house, as referred to in the description of the aëration basin, and this causes one or more additional hydraulic valves on the inlet pipes to the aëration nozzles to open and admit all the water that the pumps in the raw water station will furnish. The weirs at the aëration basin will split the incoming water into three equal parts, and two thirds will flow to the divisions of the basin feeding the filters and the third part will flow to the empty division. In passing through the third mixing chamber it will receive its dose of aluminum sulphate as in regular operation. This condition will continue without disturbances to the filter operation until the third division fills to the cross filling weir crests. As the general level commences to rise, the water level in the controller box will also rise and gradually shut down the valves on the pipes leading to the aëration nozzles until equilibrium between incoming and outgoing water is established.

The sedimentation basin has been divided as described above into compartments for reasons of water economy. The behavior of the basin at the Gatun-Agua Clara plant shows that about 80 per cent. of the sludge may be expected to lodge in the first com-

partment; that 15 per cent. will remain in the second, and that the remaining 5 per cent. will reach the third compartment. It has also been found necessary to clean basins on the isthmus when the sludge reaches a depth of three or four feet, and this may be expected every seven or eight days. With the basin divided into divisions and compartments as described, it is expected that once a week the first compartment may be cleaned without disturbing the other two compartments, except to throw them out of service temporarily; that once in two weeks the second and third compartment may be cleaned, and once every three weeks or a month the entire division may be cleaned. Such an arrangement, if satisfactory, will lead to a large saving in water over any arrangement that requires the entire division to be drained when it becomes necessary to clean, and when such necessity is brought about by the fouling of only a small portion of the division concerned; 2½-in. wash-water lines for use in cleaning the basin walls and floor will be laid in the concrete walls, and 2½-in. fire-hose outlets will be placed near the tops of the walls at the center of each compartment.

The walls have been designed as cantilevers, and they run from 2 ft. 7 in. thickness at the bottom to 6 in. thickness at the top. On the top of the walls will be laid 2-ft. wide concrete sidewalks, so that ready access can be had to any part of the basin. Night illumination will be provided by placing 14 concrete lamp posts, mounted with 250-watt Tungsten lamps covered with 13-in. diameter opalescent globes, at different points on the tops of the walls.

A basin having such a marked difference between length and breadth dimension as the one at Miraflores may seem to many to suggest much greater expense in first cost. Topographical restrictions compelled the shape of this basin, and any increase in width would have resulted in pile foundations due to the ridge being too narrow to carry a greater width than 125 ft., and the increased cost due to greater length of perimeter would be more than offset by expensive foundation work for a wider basin.

FILTER BUILDING.

The general ground plan of the filter building is rectangular in shape, and will cover a space of approximately 62 ft. wide by

175 ft. in length. It will be divided into what may be considered two separate buildings. That portion of the structure lying immediately adjacent to the western end of the sedimentation basin will have a ground plan of 28.75 ft. in width by 51.5 ft. in length, and will be three stories in height. The second portion, containing the filters, pipe galleries, and clear-water basin, will extend at right angles to the above building for a distance of approximately 148 ft., and with a width of 62 ft. The first portion of the entire structure as described above will be known as the office, laboratory, and quarters building, in distinction from that portion containing the filters only.

There will be a total of fourteen filters, placed in two rows of seven each, with the operating floor and pipe gallery running between them. Each filter will be 19.75 ft. by 21.5 ft. in plan by 11 ft. in depth from the top of the walls to strainer pipe floor. At a rate of 125 000 000 gal. per acre per twenty-four hours, each filter unit will have a capacity of 1 220 000 gal. per day. The width of the pipe gallery and operating floor between filter walls will be 15 ft.

The filters will be entirely under cover, and the outer walls will be run up a distance of about 8 ft. to form the building side walls and support the trusses carrying the roof. The steel trusses will have a clear span from wall to wall of 61 ft., and the lower chords will be curved to a radius of 100 ft. There will be 6 trusses spaced 20.75 ft. center to center. The side walls and wall at the opposite end from the laboratory office and quarters building will be pierced with large circular topped windows.

The operating floor will be placed at a level 2.5 ft. below the top of the filter walls, and access will be had to it from the main floor of the office building by a broad flight of five steps. This main floor will be at the elevation of the tops of the filter walls, and will be separated from the filter portion of the building by a concrete wall in which will be placed large circular arched openings throughout its length. An unobstructed and elevated view will thus be available over both banks of filters. On this main floor, to which the principal entrance will lead, will be located the office and the laboratory. The laboratory will be partitioned off into a room 20 ft. by 21 ft., and will have such openings as will permit a free view through the outer wall arches over the filters.

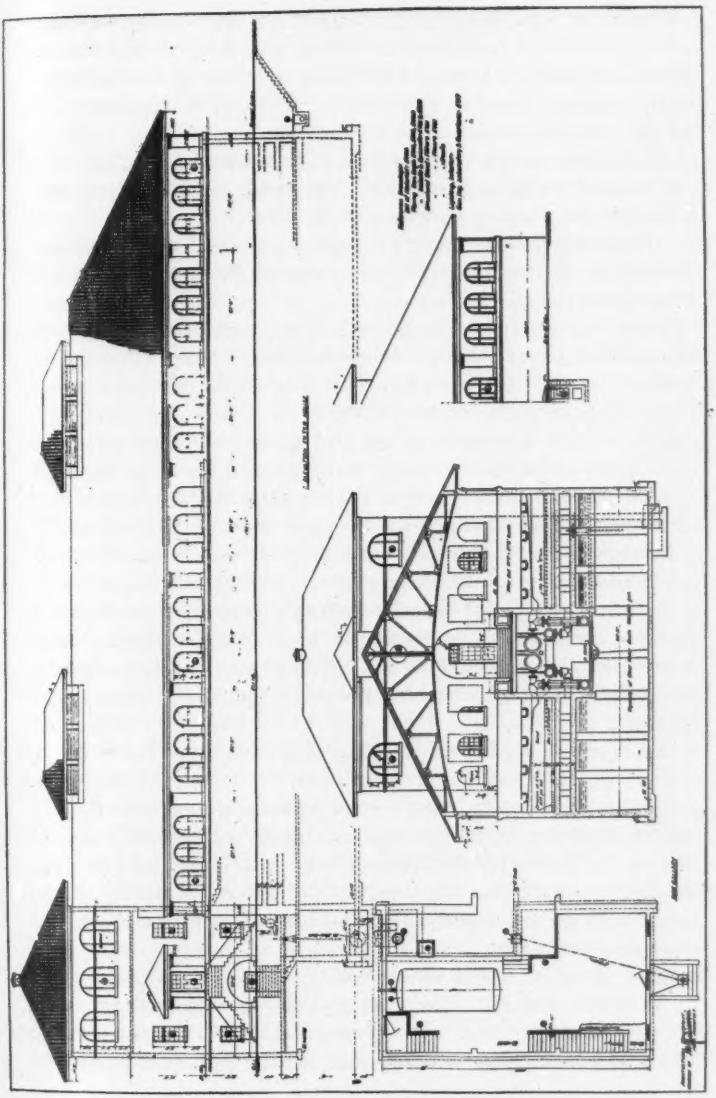

FIG. 3. FILTER BUILDING. EAST ELEVATION AND SECTION LOOKING SOUTH.

The third floor of the office, laboratory, and quarters section will contain three bedrooms, lavatories, and shower baths for the accommodation of chemists who will be in charge of the operation of the plant. Access to this floor will be had by concrete stairs off the main floor below.

The basement or first story will provide room for a compressed air receiver, transformers, storage and small repair benches, and will open directly into the pipe gallery between the filters.

A clear-water basin, having a depth of 12 ft. and a capacity of approximately 900 000 gal., will extend over the entire area below filters and pipe gallery floor.

In the design of the filter unit the usual under-drainage system of collector pipes has been abandoned and the false bottom or pressure-chamber plan adopted. The idea of the false bottom was first suggested to the writer by Mr. J. N. Chester, of Pittsburgh, but before the decision to adopt this system was made, more or less extensive experiments were undertaken to ascertain the most suitable type of strainer system; the relation between area of bed and total area of strainer openings; the pressure required in the pressure chamber for varying rates of wash from 5 gal. to 20 gal. per minute per sq. ft. of filtering area; the most suitable depth of gravel bed; the possibilities of having a mixing in the event of sudden admission of large quantities of wash water; the resulting uniformity of agitation over the bed; the most suitable arrangement of wash troughs, and the shapes of the trough edges acting as weirs.

A fully equipped filter 5 ft. square was built with a false bottom having an 18-in. space between it and the filter bottom proper. This filter was operated with certain depths of gravel and sand and different arrangements of troughs. Space will not be taken to discuss the results of the experiments with this small filter, but it may be stated that the design of the filters for the Miraflores plant as described herein is based as far as possible on the results obtained from them.

Each filter, as stated above, will be 19.75 ft. by 21.6 ft. by 11 ft. inside dimensions. The walls and bottom will be 12 in. thick, of reinforced concrete. The pressure chamber will extend over the entire area below the floor, and will be 2 ft. in depth to the

pressure floor. This floor will also be of reinforced concrete and 14 in. in thickness.

The filter has been designed for a normal washing rate of 15 gal. per sq. ft. of filtering area, and the pressure chamber has been designed to withstand a maximum pressure of 28 lb. per sq. in. The presence of a clear-water basin beneath the filters complicated the design to a certain extent in view of the necessity of taking care of the great vertical loads as well as the bursting pressure that will result from the above unit pressure. This, however, has been worked out satisfactorily on the drafting table and a full-sized test of a section of the pressure chamber will shortly be made to determine the most advisable manner in which to make the construction joints and also to learn what leakage may be expected under actual operating conditions. It is, of course, obvious that the greatest care must be taken in the construction of this part of the filter, else the results may prove disastrous.

In the floor carrying the gravel and sand will be placed, on 6-in. centers, $\frac{3}{8}$-in. brass pipes connecting the pressure chamber with a modified form of the ordinary hemispherical brass filter strainer. Each of these pipes will bend 180 degrees just above the floor, and end in the brass strainer looking down toward the floor and $1\frac{1}{4}$-in. above it. The strainer will be a slightly buckled circular plate $\frac{7}{8}$ in. in diameter, pierced with twenty-five $\frac{1}{16}$-in. holes and swedged into a hexagonal base ending in a $\frac{3}{8}$-in. threaded pipe connection for screwing into the $\frac{3}{8}$-in. brass feed pipe from the pressure chamber. There will be 1 677 of these strainers in each filter, giving a relation between area of filter bed and area of openings in strainers of 475 to 1.

Each filter will be laid with three sizes of gravel to a total depth of 24 in., and one size of sand to a depth of 30 in. The first layer of gravel will be 8 in. in depth and will consist of that size which will pass a screen having 2-in. square mesh, and be held on a 1-in. square mesh. The second layer will be 12 in. in depth and will be that size which will pass a screen having 1-in. square mesh, and be held on a screen having $\frac{3}{8}$-in. square mesh. The upper layer of 4 in. will consist of size of gravel lying between $\frac{3}{8}$ in. and $\frac{3}{16}$ in. in diameter.

The same sand as used in the Agua Clara plant and in the new

Colon plant will be placed in these filters. This sand is the so-called Chame sand, taken from the beach south of Panama Bay and used for general construction purposes on the Isthmus. By proper washing and separation, a very suitable filter sand can be obtained, having a mean effective size ranging from .35 to .45 mm., and uniformity coefficient from 1.2 to 1.8.

The filter troughs will be constructed of concrete, and will consist in each filter of one central trough running at right angles to the operating floor and four lateral troughs emptying into same from each half the filter. These troughs have been so designed as to cause a depth of flow over their edges of 1 in. during washing. This will produce sufficient velocity of approach as to draw scum from a maximum distance of 2.5 ft., or half the distance between edges of lateral troughs.

While it is not expected to use air in connection with the ordinary operation of the filter, a separate air system will be installed between the second and third layers of gravel. It has been the writer's experience that caking of the sand bed in separated small areas can occur even in beds with high wash rates, and the assistance of air in breaking these up seems to be of considerable advantage. It may prove, however, that the uniformity of the wash from the pressure chamber system will be such as to eliminate the spotting or caking in the bed, and in this case the air will not be necessary except for the agitation and mixing as described in other parts of this paper.

The filters will be piped up in two banks of seven units each. That is to say, the piping leading to and from the filters will be in duplicate on each side of the longitudinal center line through the filter pipe gallery.

The water from the sedimentation basin will reach the filters through two 30-in. diameter cast-iron mains hung side by side from operating and office floors. Twelve-inch diameter influent pipes branching off each of these mains will connect into the filters. The wash water will be supplied through two 16-in. diameter mains running throughout the length of the pipe gallery on each side of the center line and about 7.5 ft. above the floor. Each filter will be connected off one of these lines by a 14-in. branch to the pressure chamber, and off this branch will lead a 10-in. effluent

pipe to the controller box. The rewash pipe will be 6 in. in diameter, connected directly into the sewer line through a loop rising above the level of the sewer a sufficient distance to keep back pressure from reaching the filter in case the rewash valve should be accidentally left open during the washing of adjacent filters.

The sewer lines will be two 16-in. cast-iron pipes, laid directly on the floor of the pipe gallery.

The wash water will enter the building from the 300 000-gal. tank, referred to on page 241, in a 20-in. diameter cast-iron main. Immediately back of the point where this line splits into the two 16-in. mains will be located a 20-in. Venturi meter. The recording apparatus for this meter will stand on the operating floor, so that the operator can see and record the amount and rates of wash being admitted to the filter.

All valves for operating the filters will be hydraulically operated from solid black slate operating tables, located on the operating door in front of each filter. On these tables will be mounted the usual sample cups, indicator recording loss-of-head gages, air and wash-water pressure gages, and the necessary controlling levers for the valves. Small 10-watt green and red lamps will project from the top of the tables and so wired between controller and loss-of-head gages as to indicate filter in or out of service, or ready to clean.

The floor of the operating gallery and the office and laboratory will be laid with 6-in. square dark-red Welsh tile. The breast walls of the filters will be treated with sulphate of zinc wash and painted with black enamel paint. All surfaces above the tops of these walls will be painted white.

The level of the pipe gallery floor on which the controller described below will rest will be placed about four feet below the bottom of the filters, and arrangements have been made so that the filters can be operated with or without negative head.

The head house, office laboratory, and quarters, and the filter building will have roofs of special Spanish type dark-red tile, laid on $2\frac{1}{2}$ in. of sawdust concrete, to which the tile will be nailed. The sawdust concrete will be laid on asbestos corrugated sheathing bolted to the purlins of the steel trusses.

The laboratory will be fully equipped for all work in connection with complete microscopical, chemical, and bacteriological analyses of water.

INJECTION CHAMBER.

The clear-water basin will be connected with the injection chamber by a 30-in. cast-iron main, as described on page 241. On this line will be placed a 30-in. Venturi meter which will indicate and record the flow of all water leaving the clear-water basin. The indicating-recording apparatus will be placed on the floor of the wash-water pumping station, referred to above as United States Pumping Station No. 2, located about 50 ft. distant.

The hypochlorite orifice boxes, with their measuring devices as described below, will be placed in this pump station, and from these boxes piping will lead to the injection chamber.

The injection chamber will be in a general way a concrete pressure box approximately 24.5 ft. by 17 ft. by 6 ft. inside depth, divided longitudinally into two main divisions. The water may be allowed to pass through both divisions simultaneously, or through one while the other is closed down for cleaning or for repairs.

Each division will be divided into compartments having curved and flat faced concrete baffles placed in them, of such design and arranged in such a manner as may be expected to give the utmost agitation and mixing to the water as it passes through. Upon entering the first compartment of each division, the water will pass through two vertical slots about 5.5 ft. in length by 6 in. in width, in front of which, splitting the flow, will be placed two perforated bronze solution pipes which will enter the top of the chamber through a regular stuffing box.

The water after receiving its dose of bleach will pass through the baffles into a terminal pressure compartment, and from this into the 30-in., 20-in., and 16-in. mains leading to Ancon, and into the 20-in. line leading to the suction side of the wash-water pumps in pumping station No. 2.

The injection chamber will be under a maximum pressure of 17 lb. per sq. in., and the solution of hypochlorite of lime at a strength of not more than two tenths of one per cent. will be pumped from

the measuring orifices in the pump station into the injection chamber by small bronze centrifugal pumps.

EFFLUENT CONTROLLERS FOR FILTERS.

In considering the type of effluent controller to be adopted for the filters, it was thought that simplicity of construction and operation in a controller was more to be desired than the more or less elaborate apparatus involved in certain types of controllers now on the market, and it was therefore decided to design an automatic control for the ordinary hydraulic valve placed on the effluent pipe so as to cause it to feed at constant head a bronze orifice placed in a box on the floor of the pipe gallery, and discharging through same into the clear-water basin.

The controller as finally adopted will consist of a simple round open-top concrete box, approximately 2.5 ft. in diameter and 3.5 ft. deep, cast on the floor of the pipe gallery; an adjustable circular bronze orifice cast in the floor and opening into the clear-water basin; a copper float 2.25 ft. in diameter carrying a stem which will operate a small vertical piston valve, and a 10-in. hydraulic valve placed on the effluent line leading into the controller box.

The piston valve will act on the principle of the ordinary four-way valve, and admit water, through small piping, to either top or bottom side of the hydraulic cylinder, according as the water in the controller box rises or falls in depth over the orifice. The depth of water for any rate of flow from the filter on the orifice having been determined, and the float set at this height, the hydraulic valve upon being opened, admitting water into the box, will be actuated in such a way by the piston valve as to maintain a constant head on the orifice through conditions of maximum to minimum heads from the filters.

The small piping from the piston valve to the hydraulic cylinder has been so arranged with branch piping to the regular four-way valve on the operating table that the filter can be cut in or out at any time by throwing the four-way valve lever on this table; at the same time automatically cutting out the operation of the controller piston valve.

To change a rate of filtration, it will be only necessary to raise

or lower the controller float to correspond with the increased or decreased head desired on the orifice to give this change. The action of the 10-in. valve is necessarily rapid, and the filter upon being thrown into service after cleaning will go almost instantly into its fixed rate of discharge and maintains the rate constantly until the effluent valve reaches its full open position.

ALUM AND HYPOCHLORITE OF LIME APPARATUS.

As stated in the description of the head house, the hypochlorite and alum solutions will be prepared on the third floor of this building.

The alum will be placed after weighing on a removable wooden floor over the top of the solution tank. This floor will be bored with $\frac{1}{4}$-in. holes, $\frac{1}{2}$-in. on centers. The alum will then be dissolved by heavy sprays playing upon it until it has passed into the tank beneath.

Agitation of the solution will be accomplished by an ordinary motor-driven adjustable bladed bronze propeller running in a conical-shaped compartment placed on the floor of the tank. This compartment will be ported and the solution will be drawn in at the top and driven out at the bottom through these ports. The propeller shaft will be driven by a $7\frac{1}{2}$-in. h.p. motor through a bevel gear and rawhide pinion. The thrust bearings for this shaft will be placed at the top of the tank so that the bottom end of the shaft will run in a simple guide bearing and thus eliminate bearing troubles that would arise from the action of the solution on the metal parts of a bearing placed at the bottom. The solution will be carried from either of the two solution tanks through a 2-in. bronze pipe leading directly into a constant head regulating box placed on the second floor of the head house. This orifice box with its regulating devices will be in duplicate so that repairs or cleaning may be effected without interruption to the supply of solution.

The solution will enter the orifice box through a bronze ported cylinder within which will work a movable shell attached to a vertical spindle ending in a copper float about 20 in. in diameter and 4 in. deep. This cylinder will be $2\frac{1}{2}$ in. in diameter and the

cylindrical shell will be $1\frac{1}{2}$ in. in diameter. A movement in the vertical plane of one quarter of one inch will give full flow into the box, and this will be the amount of variation in head on the orifice outlet from maximum to minimum flow.

The orifice measuring the flow passing from the controller box to the perforated pipes over the raw water will be an annular slot with a movable cover placed over it, which when revolved about its center will throttle the slot in such a manner as to change its size in its circumferential dimension only. This cover will be actuated by a vertical shaft leading to the top of the controller box wall, where it will end in a gear and pinion and indicator pointed controller handle. A horizontal plate placed immediately above the gears, below the indicator, will be divided into degrees of opening of the orifice slot, and the indicator or pointer will give the exact opening in degrees on the plate. The gear and pinion is introduced for multiplying the angular motion of the orifice cover by two, so that a small angular throttling of the orifice can be obtained.

The solution in passing the orifice will fall into a small concrete trough, in the sides of which will be placed three bronze sharp-crested weirs, $1\frac{1}{2}$ in. to 2 in. in length, placed at exactly the same elevation. These weirs correspond to the three mixing chamber units and serve to split the solution equally into two or three parts according as two or three mixing chambers are in operation. The solution will fall from these weirs into $1\frac{1}{4}$-in. bronze pipes ending in perforated pipes placed directly over the discharge from the weirs delivering the raw water from the aëration basin into the mixing chambers. The solution will thus finally be delivered to the raw water in 30 to 90 $\frac{3}{16}$-in. diameter streams, spaced about 6 in. apart.

The hypochlorite of lime will be delivered to the storage room set aside for it on the upper floor of the head house in 50 lb. containers. The lime will first be reduced to an emulsion and then admitted through screens to the solution tanks, where it will be brought to a strength from one tenth to two tenths of one per cent. There will be three emulsion tanks constructed throughout of bronze. These tanks will be approximately 24 in. square by 20 in. deep, with cylindrical bottoms and watertight covers.

They will be placed in line on the floor of the storage room about 10 ft. distant from the solution tanks. In the horizontal axis of each box will be placed a shaft passing through the sides and carried in watertight bearings. In this shaft will be placed stirring blades with about 1½-in. faces. These blades in revolving will pass between baffles projecting from the bottom of the box. The clearance will be such as to break all particles to at least ½-in. size. The shafts will end in pulleys which will be driven by belts running off tight and loose pulleys carried on a line shaft placed in the rear and parallel to a common axis through the three boxes. This shaft will be direct connected to an induction motor.

Each box will be equipped with fixed water connections for filling, and with a water ejector which will deliver the emulsion from the box to the solution tanks without any handling beyond the turning on of the ejector valves.

One or two 50-lb. batches of lime will be placed in the emulsion box, the cover clamped down, and the water turned on until the box fills. The mixture will then be stirred by the blades on the shaft revolving at high speed for a few moments, and finally the emulsion will be ejected directly into the covered solution tank, where it will be further mixed by compressed air for a period of one hour, and then allowed to stand until thrown into service.

Experiments with this character of apparatus indicate that a minimum of handling and exposure to the air, and consequently a minimum of fumes, may be expected during the operation of preparing the hypochlorite solution.

In order that it might be possible to have the indicating recording apparatus of the Venturi meter on the 30-in. effluent line from the clear-water basin immediately adjacent to the hypochlorite measuring boxes and orifices, it was decided to put both in the wash-water pump station near the injection chamber. It was also decided to place the solution orifice under constant manual control according as the meter indicated the flow, instead of attempting any automatic device.

The solution will be delivered to the pump station controlling apparatus in either lead or bronze pipes. It will be discharged through an hydraulically controlled sliding hard-rubber orifice into a small float chamber, and by means of a float and piston

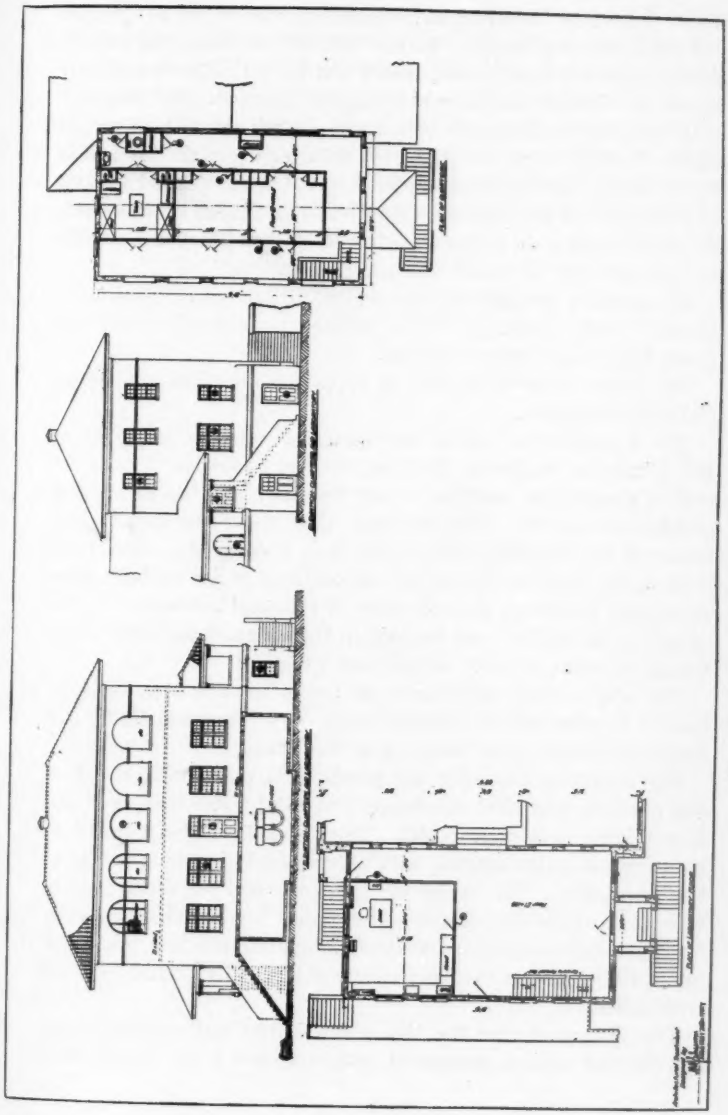

FIG. 4. OFFICE, LABORATORY, AND QUARTERS.

valve operating the hydraulic cylinder of the orifice a constant head will be maintained. In the wall of this float box will be placed a hard-rubber orifice, which will be varied in opening by means of a milled head screw manually operated. An indicator scale reading to thousands of gallons per minute will be placed above the orifice and so graduated that for a certain fixed head on the orifice and for a certain fixed solution, the desired amount of chemical will be delivered for any flow indicated by the meter by simply setting the orifice indicator to read on the scale the same as indicated by the meter indicating apparatus.

The solution passing this last orifice will fall into a small open chamber from which it will be pumped by a small centrifugal pump into the injection chamber.

The entire chemical measuring apparatus described will be installed in duplicate.

The hypochlorite measuring apparatus recently installed at the Miraflores temporary pumping station is similar to that described except that pumping is not necessary, and has given very satisfactory results. The presence, throughout the twenty-four hours, of an attendant whose duty it is to keep the orifice scale reading the same as the meter and to keep a log on both gives reasonable assurance that the flow of chemical meets the fluctuations in the mains; and further, in the event of anything going wrong, it is immediately noticed and remedied.

The cost of such attendance on the isthmus is low, as satisfactory services can be obtained from West Indians at thirty-five dollars per month on a twelve-hour shift basis.

The operating force for the purification plant will consist of one chemist, two filter operators, two head-house men, and one hypochlorite orifice attendant. The chemist will be required to be a trained water analyst, with experience in handling plants of this character. The others on the force will be West Indians who, it has been found, can be developed into reliable operators for the straight mechanical work of manipulating valves, etc. The plant will be run on two twelve-hour shifts and with full force for both shifts.

The estimated cost for this plant figures out approximately $22 000 per million gallons of water delivered per twenty-four

hours. In considering this, however, it should be noted that the comparatively long sedimentation period calls for a large and correspondingly expensive basin. This, together with difficult topographical features encountered, requiring the placing of the plant on a high, narrow ridge, and also with the more or less elaborate aëration treatment not ordinarily embodied in plants of this character, makes for a figure per million gallons delivered per day that may at first glance seem a little higher than usual for plants of this type and capacity.

THE CONSTRUCTION OF DAMS.

BY A. E. WALDEN.*

[*Read September 9, 1914.*]

There are many things to be considered in designing dams, and especially one of the commonly called "gravity type," or, rather, of the solid masonry type, which will be here called the mass type; the gravity type will be that as constructed by Beardsley and Amburson and Ransom.

There are many dams that have been constructed on foundations so unsafe that they would be immediately condemned if they were to be proposed and erection started to-day.

In making examination of a dam site, test pits or borings should be made for a good distance above the dam site to determine the composition of the soil or strata under the dam, the trend of the stream, if on rock, noting if these are at right angles to the stream or with the stream, and if the stone is subject to water holes; also the character of the ledge, whether seamy or not, and if it shows rapid disintegration where exposed to the atmosphere, and if under water, that it is easily worn away by the action of the water, as in some limestones.

In some cases it will be found that in the bed of the river there are two classes of stone, one portion of which is soft and the other hard.

A careful examination of the banks should be made for suitable abutments and abutment foundations, and the quality of the soil composing them; also the slope of the underlying rocks, so that steps may be taken to prevent seepage through and eventually a washout.

There are several ways that have been employed by engineers in determining the proper length of crest, all of which are more or less efficient when properly applied, as are also certain empirical

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rules, where run-off data cannot be obtained, such as basing the run-off on a certain number of feet per second per square mile, certain instances of which will be given here.

In one case that came to the writer's notice the dam was constructed on a basis of three feet of crest per square mile of area which is hilly and steep, based on a rule that there should be on normal conditions at least one foot of spillway length for each square mile of drainage area, and this multiplied by three can take care of flood conditions. This dam failed many times, causing great property damage, but was finally constructed so that the spillway section would have a crest equal to taking the run-off at 20 cu. ft. per sq. mile at a velocity of one foot, and dividing this result by an assumed depth at the crest, considering it as a rectangular section, no allowance being made for the well-known weir action and of velocity of approach over such a crest. No trouble has since been experienced. This determination was made after an examination of the stream's banks for height of water, its depth at this point as compared with the width and depth of water at other points and for several hundred feet above and below; also noting the heights to which débris had landed; from information given by people living along the stream as to flood heights; from the drainage area and from rainfall data which had before for some reason given results too small, to some extent probably due to the character of the drainage area, its topography, and the condition of the soil at certain times.

With 20 cu. ft. at a velocity of one foot per second and the banks 5 ft. high, it was assumed that the water reached 5 ft., but with 20 cu. ft. used as a basis and the dam lengthened to 146 ft., and estimating a crest depth under these conditions of 3 to 4 ft., this stream has since been measured for surface velocity during high water and an average velocity, on the surface, of 10 ft. per second obtained, with a depth of 20 in. at a point far back of the crest so that the increased velocity of the water at the crest of the dam did not affect it. Undoubtedly the velocity of the water varied at various depths, but this could not be obtained.

Assuming the average velocity at 10 ft. per second, and a sectional area of 146 ft. by 20 in., the approximate discharge per square mile in this case was 99 cu. ft. per second, and the greatest

depth of water so far noted on the crest of this dam has been 3 ft. It is possible under these conditions that the velocity was from 15 to 20 ft. per second, but this could not be measured at the time, on account of lack of preparation.

In another case a dam was constructed for a crest depth of 5 ft. for a drainage area of about 300 sq. miles. This dam was 200 ft. long at the spillway, with about 1 000 ft. of earthen embankment about 18 ft. higher than the spillway section. The 5 ft. depth at the crest has been exceeded many times, and the gage has shown a depth of 11½ ft. on the crest, which was beyond data based upon the government report's gage readings at that time, and would be about on the approximate basis of 7 cu. ft. per second per sq. mile.

From an examination of many streams, watersheds, and dams, it would seem that one may expect to find that the run-off will vary from 50 to 100 ft. or more per second, and in some cases it has been considerably more than the maximum amount noted for a hilly section, that will give a quicker crest rise than a flat section will do, owing to the fact that the water cannot spread over any large area.

It may be assumed that a certain portion of the flood reaches the crest in the first hour, a certain portion in the second hour, and so on to five or six hours, or more, but this cannot be accurately determined beforehand with the data we have to-day.

Every effort should be made to obtain data from other dams on the same watershed, if any, or on similar watersheds in the vicinity, as to the rise in a given length of time after a heavy rainfall, so as to determine the lapse of time between either the beginning or the maximum rainfall and the maximum crest rise. Rainfall data show that a maximum rainfall of 4 in. in one hour may be looked for, and from 8 in. to 10 in. in twenty-four hours. On this basis there would fall for each square mile in the first hour, 9 288 800 cu. ft. (1 in. equals 2 322 200 cu. ft.). Then the question would arise as to what part of this reaches the dam the first hour, and each succeeding hour until the maximum crest height is reached, and the effect the condition of the soil and the ground water content has on this. From J. B. Francis' records, the indication would seem to be that a depth of rainfall varying from 6 in. to

11 in. or more, with rates about as follows, may be looked for: 4 in. in two hours, 6 in. in about twenty hours, and 9 in. to 10 in. in thirty hours, etc.

For the rainfall and flood conditions, Fanning's formula has been much used, as well as others, but must be applied with care for the particular location, the period of the year in which the rainfall occurs, as on frozen ground or with a light fluffy snowfall it requires 15 in. or 20 in. to equal 1 in. of rainfall. While assuming 4 in. to 5 in. of wet soggy snow to equal 1 in. of rainfall, the rainfall combined with the water from the melting snow with the frozen ground underneath will give quite sudden changes in the flood conditions, which will exceed any rainfall obtained from hourly rainfall records; recording gages at dam, however, would show this.

The effect of impoundings or pondage in reducing flood conditions, if the area is sufficient, where there is one or more dams above the one to be designed, should be considered. The crest of the dam under design should be proportioned to care for the failure of at least one, or more, of these dams in addition to that of flood conditions, depending on the location of towns and villages

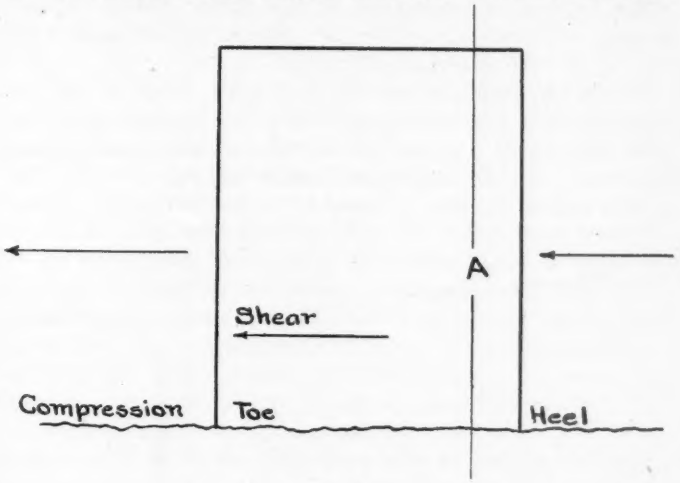

FIG. 1.

below, and the property value and loss of life likely to occur in case of such failure.

In the design of a dam of the mass or solid section type, as shown by section, Fig. 1, the dam may be considered as a beam fixed at one end and having an uniform load, and as such may have shear at the joints, tension in the upper face and at the heel, with compression at the toes, etc.

Then to care for tension in the upper face, steel may be provided, but its calculation would be to some extent theoretical. In any event, if securely anchored to the rock formation in drilled holes, and the steel provided with split ends and wedges, and afterward grouted in carefully, this method would certainly add to the stability of the dam, especially when the dimensions were properly proportioned to care for shear. Steel bars may be embedded at an angle of about 30 degrees, as shown in Fig. 4, or some other angle, with the horizontal so that the steel will take tension as far as it is possible to make it do so under these conditions.

In preparing the foundation, care must be taken to remove surface rock that has deteriorated, to a depth that test holes show to be safe, and then the surface under the dam should be roughed, either toothed or sawtoothed, or in a similar fashion, so that pressure will tend to force the dam downstream and against the toothed or roughed surface as shown.

This work should be carefully performed, either by the use of dynamite or steel points and wedges, but dynamite should be used in the hands of an experienced man who understands placing shots, and especially is this true of the cut-off wall at the heel, for if such placing is done, it should be carried out in the manner

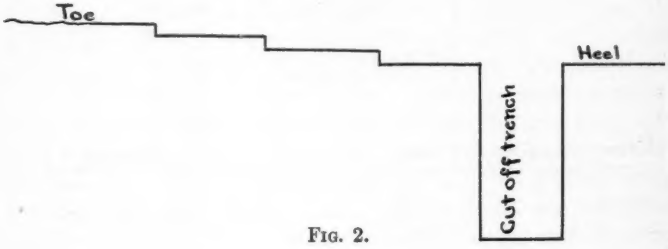

FIG. 2.

described, care being taken to so set the upper drill holes to line for a narrower cut than is required, and then remove the shattered stone by wedges and points, as it is necessary that the cut-off wall should not be shaken to such an extent that there will be liability of leakage to the downstream side.

A careful note should be taken to see if seams run at right angles with the stream, or partially with the stream; also the character of the stone and of any change in the composition, as there are cases where there are one or two different rock formations in the same river bed.

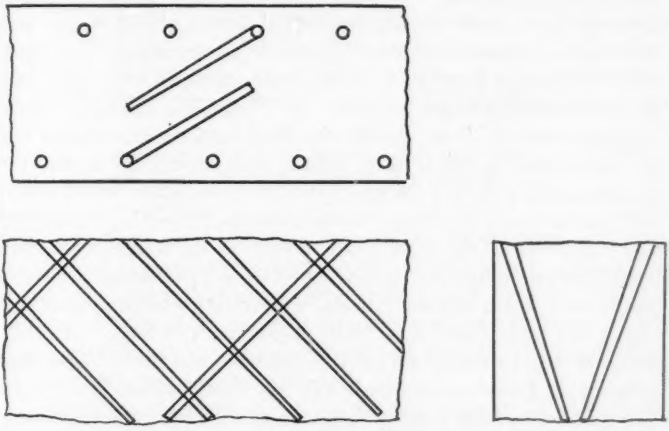

FIG. 3. METHOD OF DRILLING.

One or two test holes should be exploded with various charges, at some other point, to determine the proper charge to be used, but vertical holes should not be used, unless absolutely necessary. In this respect it might be said also that a regular 500-volt current will explode twenty holes, and such a number of holes exploded simultaneously will do better work than three or four holes exploded at a time. Holes may be placed as described below:

Holes running with trench on each side, about 4 ft. apart and at an angle of 45 degrees, with extra holes at each end at same angle, looking the other way. The depth of these holes will depend

on the depth of trench required and the width of the same. In addition to this, holes may be drilled from side to center as shown in the end section, Fig. 3.

The writer has seen trenches cut in this manner, by men who understood tunneling and channeling, that would meet the conditions required in every respect.

Test holes should be drilled to sufficient depths, 10 to 20 ft., more or less, to be sure that no seams or underlying strata of clay underly the rock, and tested with compressed air or water to at least 100 lb. pressure, and pressure maintained for such a time as will surely determine the condition in these test holes. Shale formations are liable to large seams; overlying strata of clay and limestone formations to water channels or recesses. The holes should be drilled from 10 to 15 ft. apart, more or less, depending on the conditions found to exist.

There seems to be no reason why solid section dams should not be constructed in the form of arches that extend from the toe to the cut-off wall, and the spaces under these arches would effectually care for any uplift due to water seeping through or under the dam, supports to the arches, or haunches of the arches, of course, being carried sufficiently below the surface to effectually protect them from wash and undermining, and would be more satisfactory than large pipe placed 8 to 10 ft. apart, more or less. Or 10 in. split tile may be employed for this purpose, which would be more satisfactory than a solid tile, but in any event should be covered with loose stone so as to allow free access to the tile from all sides.

There is another condition that must be given consideration in this work, and that is, at the toe of the dam there will usually be found a pool cut out in the rock or other surface, that at or near the center of the spillway section will have a depth of from one third to one fourth of the height of the dam; and it will be found that if this pool is filled with concrete, it will eventually wear to this same depth and there remain about stationary. It would seem to be good policy to retain these pools, unless some other method were taken to care for the action of the water at this point. Some types of dams would probably be less affected than others.

The solid dam may be reinforced and tied to bedrock in the

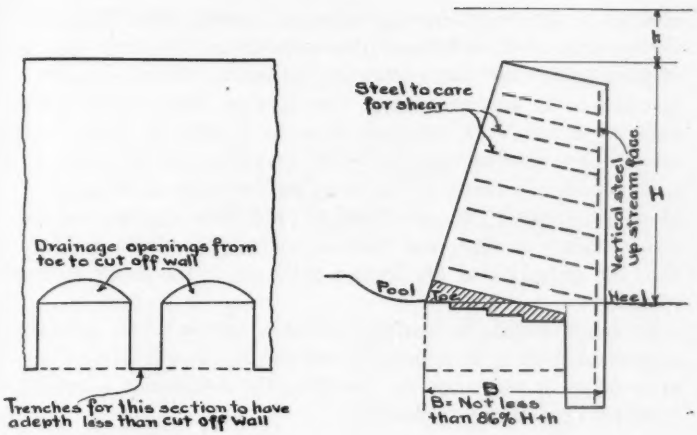

FIG. 4. SECTION OF SOLID DAM SHOWING HOW THE ARCH CAN BE USED FOR DRAINAGE FROM CUT-OFF WALL TO THE TOE.

cut-off portion, as described before and as shown here, and thus would take tension in the upstream face of the dam, in addition to which the diagonal bars at some angle would tend to take the tension due to sheer and prevent any tendency to sheer in the horizontal plane, or where new work was tied to old, in case that the joint was not properly cleaned.

The trenches for the haunches for the supports of the arches should have a depth at least equal to the pool and the cut-off wall, preferably somewhat below this. These arches should extend back to the cut-off wall, which should be made sufficiently strong for the purpose, and will give a more efficient drainage than it will be possible to obtain with pipes of any kind.

Referring to the earthen embankment as employed at the abutment ends of some dams, the following construction was employed by the writer, and tests carried on every day for several years to see if there was any increase of the water in the test well, Fig. 5, but no increase was found.

Again, from the core out to the toe every 20 ft., double lines of porous drainage tile were laid from the double line of tile that skirts

the core to the double line that skirts the embankment just under the toe and to the outside of the embankment to some suitable disposal point that would allow of the amount of water running to waste to be measured, from time to time, these drains being covered in turn with crushed stone to a depth of 6 in.; the reason for this being that the writer excavated on one such embankment to the center of the same, the embankment being composed of a gravelly soil, and found no water until the center of the embankment, or core, was reached, showing that the drainage kept the embankment dry from a point above the center to the outside.

As before stated, the surface or foundation on which the dam or embankment is to be constructed should be excavated either in trenches or as shown, as this gives the foundation a greater frictional or sheering resistance.

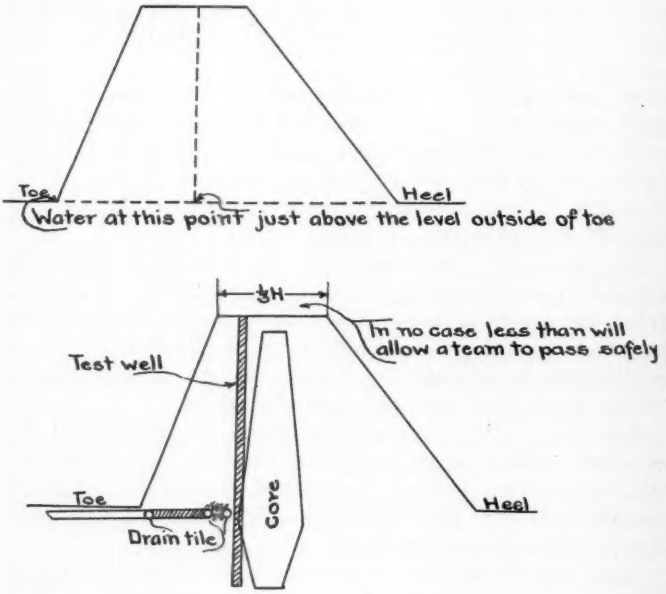

FIG. 5.

Table 1 gives data on dams, the depth and velocities of waters at the crest for which these were designed; and the actual depth obtained will give an indication of the conditions as they actually exist.

TABLE 1.

Dam.	Square Miles.	Velocity of Approach. Feet.	Designed for Crest Depth. Feet.	Actual Crest Depth. Feet.	Length of Spillway. Feet.	Estimated Maximum Run-off. Cubic Feet per Second.
1	4 185	8.5	9	16.5	1 000	50
2	4 475	8.5	13.5	14.4	1 000	50
3	3 085	..	16.4	18	1 000	..
4	1 545	8	8	9.5	890	60
5	7 000	..	6	...	318	..
6	19 600	..	12 and 5	...	1 500	..
7	66 000	..	12	10	700	..
8	1 380	..	7	2.2	400	..
9	5 760	..	15	12	1 078	..
10	400	..	5	3.6	120	..
11	3 560	..	(Could stand 9; stand flood of 50 000 sec. ft.)	4.4	1 108	..
12	15 800	..	15	...	480	..
13	16 600	..	15	...	500	..
14	1 270	..	5.5	8	260	..
15	.....	..		...		..
16	26 766	..	17.5	...	2 350	..
17	300	..	5	11	200	..
18	320	..	5	8	119	..

Dam No. 18 was designed to care for 4 400 sec. ft.; had a total crest length of 450 ft. and a spillway section of about 120 ft., and under flood conditions water rose 8 ft. above spillway section and 3 ft. over the crest, the estimated discharge being 14 500 sec. ft.

There is one other point in the case of gravity dams, Fig. 6, in that the factor of safety of 4 for deck loads has been used, but consideration should be given the following sketch (Fig. 6), also the cost of such work. It is manifestly certain that no load will ever be obtained that would stress the deck to call for a factor of 4, or even a factor of 2, and that a factor of $2H$ would be amply safe even for ice, as with a sloping deck such a factor would protect it from floating blocks or a plane of solid ice, as the blow would be

glancing; and again, the silt which fills in on the deck would act as a cushion. Then again, floating objects are most apparent at flood when the water on the crest is deepest, which would tend to carry these floating objects safely over the crest. And in any ev .t, the stress in the material would not exceed the normal load stress effect. It may be said that load stress is uncertain. This may be true of some dams.

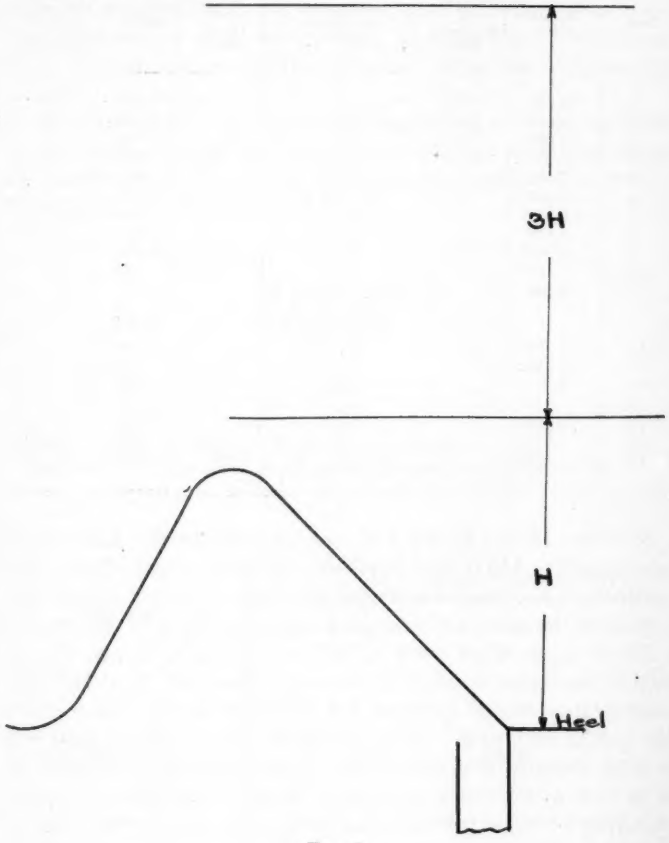

FIG. 6.

Now, the writer is not advocating a construction that would be unsafe under any consideration, but that more careful consideration be given these conditions on account of cost in a safety factor for loads that would be both safe and economical in so far as the cost of material and construction were concerned, but without going to extremes for a condition that will never be reached.

Records should be kept of the depths of the waters on the crest of the dams at all times, and the cost of an efficient instrument for this purpose is small; the one in the cut here (Fig. 7) shows a simple method of obtaining such records, which, together with the records for rainfall, and comparing the depth of rise on the crest of the dam and the time relative to the maximum rainfall would give data that would be invaluable, in a short time.

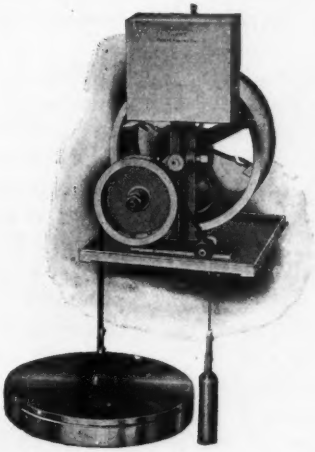

FIG. 7.

Records should also be kept of the soil strata through which excavations for test pipes and test holes pass.

The question of frost at times may have to be considered.

Every available record should be used to determine the run-off from the rainfall on a given watershed, as the run-off and the time of the maximum run-off are affected by so many conditions

that there should be as few guesses as possible, and even the records should have a reasonable percentage added.

Acknowledgment is hereby made of the assistance and data given by the following engineers in the preparation of this paper: H. N. Savage, M. H. Gerry, C. A. Mears, A. E. Peirce, H. W. Connell, J. C. Lathrop.

THE AUTOMOBILE AS AN EFFICIENCY AGENT IN WATER-WORKS MANAGEMENT.

BY GEORGE W. BATCHELDER, WATER COMMISSIONER, WORCESTER, MASS.

[*Read September 10, 1914.*]

In these times of improvement in all directions, the automobile is recognized as an agent of speed and efficiency in the transporting of men and materials.

The city of Worcester has long been known as conservative to a great degree, and it was not without considerable sharp criticism that the first municipal automobile was put in commission.

Worcester has changed, and is changing rapidly, from a condition of extreme conservatism to a live, pushing city.

The first automobile put in service for the Water Department was purchased in February, 1909; there are now eight machines in service, but the equipment is not quite complete.

These automobiles are numbered from one to eight, and will be so mentioned in this paper.

The costs given cover, in all cases, every expense except for the operator and stable men.

Depreciation is figured at 20 per cent., interest on investment at 4 per cent.

No. 1 car, a two-cylinder Buick equipped with a light express body, was put in service early in 1909. It was used as a meter and light repair machine and was available for emergency service at other times.

After five years of good service the little machine was consigned to the junk pile to make room for a Ford car, now about to go in commission.

During its service it carried the men to practically every meter job and to many repair and emergency jobs.

The meter service trips alone numbered 4 446 in 1909, 4 040 in 1910, 4 008 in 1911, 6,094 in 1912, 4,752 in 1913. The aver-

age daily run of this machine was about forty-five miles, — work which would require three horses.

The cost of this machine when purchased was $1 000. It cost to operate, all expenses, $1 048 a year.

No. 2 car: A four-cylinder Buick, Model 17, was bought in 1910 at a cost of $1 750.

This car is used to transport engineers and office men from the city to Kendall Reservoir, where the engineering department has been for several years engaged in constructing a dam and reservoir.

The car at other times during the day is held at the reservoir for ambulance service, or used to transport light supplies.

The value of getting the engineers in charge of any work on the job early in the morning is known to everybody. The automobile gets them over the nine miles from City Hall in short order, — twenty-five minutes instead of seventy or eighty minutes, if horses were used. The cost of operating and maintaining this machine is $1 200 per year.

No. 3 car: A Buick automobile, Model 21, was purchased originally as a touring car and later changed to a service car. It is now used for meters and light repairs, taking the place of the original No. 1 truck. Its average run is forty-five miles daily. It costs to operate and maintain $1 290 a year.

No. 4 car: A four-cylinder Pope Hartford touring car was purchased in 1913, at a cost of $2 025. It is used by the Water Commissioner and city council committees.

By having this car available, the commissioner is able to keep closely in touch with outside matters of any particular importance.

Four construction gangs are usually laying pipe in different sections of the city. Their work is inspected by the commissioner at least once every day.

The reservoirs, of which there are nine, are visited and inspected several times weekly, and frequent general inspection of the plant is made possible by the automobile.

Inspection trips of this nature cover an average of 35 miles daily. It would take two horses to do this work, and the commissioner would be in the saddle practically all day, and there would be no time for office hours.

It has been the practice to rent this machine for the use of the city council committees, for which a revenue of about four hundred dollars yearly has been received. This custom no longer exists, however, as the car is kept busy in the Water Department service. This car costs, all expenses, $1 280 per year.

No. 5 car: A Model 31 Pope Hartford touring car chassis with a truck body was bought in 1913 at a cost of $1 800; the body made the total cost $1 925. It is constructed with hangers outside the body, so that several lengths of service pipe can be carried, together with men and tools for installing services. This car makes it possible to get the work started early in the morning, long before it could be done if horses were used.

There are frequently five service-pipe gangs working in different parts of the city.

The foreman in charge, who operates the machine, makes frequent trips from one job to another, sees that his men are keeping the work going as it should, switches some men from a job which may be practically finished to another which ought to be closed at the end of the day, and picks up what would be a lot of loose ends if he had to depend on horses. The daily average run is about 45 miles. The cost of installing service pipes has been reduced about 10 per cent. since this automobile went into service. The total cost of operation and maintenance has been $1 262 per year.

No. 6 car: A Pope Hartford three-ton truck equipped with extra-size dual rear wheels makes it the equivalent of a four-ton truck. This car has been loaded many times with forty-eight inch pipe weighing 8 800 lb. or more, and has been in service practically every working day since its delivery in March, 1913, with the exception of a period in March, 1914, when heavy snows made the operation of an automobile impracticable.

Advantage was taken of this lay-off to overhaul and paint the machine.

Before this truck was purchased the department contracted the hauling of water pipes to the various places required. In 1912, the year before the car was purchased, the Water Department paid contractors for teaming the sum of $2 700.

In 1914, if the same rate prevailed per ton, the volume of busi-

ness would make a bill of $8 500 for the same kind of service. Deducting from that $1 352 paid for teaming this year leaves the truck performing a service worth $7 148, — figures which seem very large, but they are correct. It should be understood, however, that the pieces hauled in 1912 were, many of them, small, which took time for loading and unloading; the great bulk of tonnage in 1914 is made up of single and very heavy pieces, one to a load.

An example of precise comparison between the work of horses in 1912 and auto truck in 1913 is furnished by these figures:

Horses, 1912, 7 pairs, 14 pieces 48-in. pipe hauled daily.

Auto truck, 1913, 14 pieces 48-in. pipe hauled daily.

Our truck doing the work of seven pairs of horses on the same haul over identical roads, the same loading and unloading conditions.

Cost seven pairs horses and drivers, $38.50 per day.

Cost auto truck, operator, and two helpers, all expenses, interest, depreciation, etc., $13.86 per day.

The truck has hauled, this year, from March 26 to August 31, 4 692¾ tons, a distance of 5 312 miles. The greatest day's work was 101¾ tons of 36-in. pipe hauled 40 miles.

Conditions for a comparison between horse and auto trucking could not well be more clearly defined than in this example. With heavy materials, long hauls, and plenty of work to do, the auto truck completely outclasses horse-drawn vehicles.

No. 7 car: Ford runabout, used by general foreman. Two horses were required for this work. The foreman covers all his work, which is practically double the amount done when he used two horses, and he has more time to look after things at the water shop. This car costs per year, all expenses, $291.

No. 8 car: Velie 1 500-lb. truck, used for general light work. Capable of handling with ease materials weighing over a ton. This car has not been in service long enough to furnish any accurate figures of cost.

This completes the automobile equipment of the water department at the present time. Other cars will be added later as means will allow.

The efficiency of these automobiles cannot be measured in dollars and cents.

No. 1 car greatly improves the promptness of service for which it is intended.

No. 2 car carries the men to the reservoirs promptly and starts the work early in the day.

No. 3 car renders service greatly superior to that given by horses.

No. 4 car, the advantages have already been explained, as have those of No. 5.

No. 6 auto truck needs not further explanation after the example shown.

Nos. 7 and 8 cars have shown their worth.

Collectively, these machines are of great value. There are few moments in the day when several of them cannot be readily reached and rushed into emergency work. Every water-works man knows what that means when a serious break occurs — and who has not had that experience?

The responsibility which makes water-works superintendents desirous of giving good service and furnishing first-class fire protection at all times should be helped by giving them a good plant with which to do business. The automobile plays a very important part in this direction.

It costs money to maintain and operate automobiles. One serious break in a water pipe might cause a loss which would make the automobile expense seem trifling, and for that reason alone it is well to be equipped with good apparatus.

CALKING JOINTS WITH AN AIR COMPRESSOR.

BY DANIEL J. HIGGINS, SUPERINTENDENT WATER WORKS, WALTHAM, MASS.

[*Read September 10, 1914.*]

My first knowledge of the air compressor was some twenty years ago, and at that time the term air compressor loomed up mighty big to me. I was at that time a pattern maker, and the air compressor was for the famous firm of engineers, Westinghouse, Church, Kerr & Company. It was considered quite a thing to make the set of water-jacket cores which have to surround the main cylinder for cooling.

From that time on, air compressors have crossed my path in many ways. I have had four years' experience in the United States Navy, and the work that the air compressor performed in marine work was phenomenal. The compressor plant is located in any available place, and so arranged that with the hose connection, can transmit power strong enough to drive tools in isolated places. In marine work, especially in the work of drilling, riveting, and calking of the steel sides of our battleships, it is a very wonderful operation. To-day they have so ably handled the tools that a very light and powerful tool in the hands of a skilled man does a phenomenal amount of work as compared with that done with hand tools.

Air compressors are also largely used in structural work and in the machine shop. In the foundry they are used for sand-blasting castings, running molding machines, and operating air tools.

Last year, we had occasion to lay about ten thousand feet of 10-in. pipe. After making the necessary plans and estimates, I happened to get in touch with a manufacturer of air compressors, and there were some things in the small machine they offered which appealed to me for calking lead joints. The main features were that it was portable, not too heavy, and with enough power to run the calking hammer comfortably. The whole outfit cost

less than $450, and showed in the end that this one job almost paid for the machine. The first cuts which were shown me did not appeal to me particularly, as they showed a wooden bed. I took up the matter with the manufacturers and asked to have this machine made on a channel iron bed. This was done, and since that time all machines are made with channel iron beds. They had certain claims for the wooden bed, but after having our channel iron bed under severe usage, I was convinced it was the proper thing.

The machine which we purchased was directly connected with a single-cylinder, four-cycle gasoline engine, pumping directly into a vertical tank placed on the same bed. On top of the tank was arranged a safety valve and an air valve. Beyond the air valve was a slip joint and lock coupling for air hose. We had fifty feet of hose, and by placing the machine on the street beside the ditch, opposite the side where the gravel was to be thrown out, we could calk 100 ft. or practically eight joints without moving the machine. In one 5 000-ft. section, we ran across about 1 000 ft. of ledge, and rather than call in a contractor, or drilling the ledge out by hand, I decided to buy an air drill. This cost about $68, with a set of drills, and we removed 1 000 ft. of ledge. We found this was a very good investment, as we have used the machine many times since then for removing ledge, and have also found it profitable to transport it to various points in the city to remove large bowlders when we ran across them in the trenches.

Now, as to calking, we used the best Omaha lead, and instead of a straight ell, we used a beveled one, because it was necessary to have more lead protruding slightly beyond the bell end when calking with the machine. This would seem to indicate that the lead was more firmly forced into the joint, and we have never split a bell. The length of time necessary to calk a joint was nominally about three minutes to the joint, as compared with fifteen minutes under former conditions. Our first calking tools were made a trifle long, and after experimenting with them, decided that a short tool was more practicable. At first our calking gang was a bit timid in using the machine. They were under the impression it was going to cheat them out of a job, but after

a few demonstrations, they realized the machine was a powerful aid to them, and later realized the wonderful power behind the blow of the air hammer. We found that under-side calking was made much easier on account of the hard position and reaching that calkers had to assume in order to do satisfactory work under old conditions. The machine works just as well underneath as on the sides and top, where access is much easier.

In my first crew we had a fairly intelligent man to run the machine and to lend a hand in setting the pipe. I found at first that this man was addicted to the very serious habit of using a screw driver and monkey wrench on the machine, and would not do as he was told. This lasted several days, and we finally had to let him go. A high-school boy, formerly water-boy for the gang, was taken and put running the machine with the same instructions as given the former man. He proved a wonderful success and followed instructions to the letter, and we had much better results than at first.

The portable air compressor differs from all other plants of this kind as the engine and the compressor are combined in one machine. The air piston is connected on the same crank shaft as the engine piston, making what is known as a double throw method, which gives absolutely the same speed and power to the compressor as the engine. Another improvement is the piston discharge valve instead of the old-style stem-valve, which makes it possible to reduce the valve space behind the air piston to a minimum. This valve also increases the efficiency about fifteen per cent. and is practically indestructible. The compressor is also equipped with an unloader which automatically relieves it at any desired pressure up to 125 lb. The engine is equipped with a magneto which makes the use of batteries unnecessary. The gasoline supply is retained in the base of the engine.

The requirements of a properly calked joint involve a rather tedious and slow operation when performed by hand. In addition, it is expensive and lacks uniformity and reliability. This is most noticeable on the under side of a joint due to its inaccessibility. The pneumatic hammer gives an absolutely uniform joint on top and bottom.

The specifications of the compressor are as follows:

Engine — 5 h.p., hopper water cooled.
Compressor — 4½ by 6 in., air cooled.
Capacity — 23 cu. ft. free air per minute.
Size of air tank — 20 by 60 in. or 30 by 60 in.
Total weight — With 20-in. tank, 1 650 lb.; with 30-in. tank, 1 800 lb.
Total length — 6 ft.
Total width — 34 in.
Pneumatic tool capacity — With 20 by 60-in. tank, 1 pneumatic calking tool or 1 pneumatic rock drill; with 30 by 60 in. tank, 2 pneumatic calking tools or 1 rock drill.

The cost of the outfit is $436.60 complete, with a calking hammer for calking pipe, cutting or chipping bricks or concrete, and a set of 6 steels and air hose in 50-ft. lengths. We bought an Imperial air hammer for rock drill work for $60.

In conclusion, I would state that we are firmly of the opinion that the air compressor for calking lead joints and for rock drilling has passed the experimental stage in water-works construction, and I would heartily recommend it to any superintendent or engineer for this sort of work.

DISCUSSION.

Mr. William C. Lounsbury. I would like to ask the speaker whether he found it necessary to obtain old calkers or not, or whether he found he could employ cheaper labor.

Mr. Higgins. You can employ cheaper labor. It is perfectly satisfactory, and makes a considerable saving.

Mr. Lounsbury. Will you tell me the type of hammer that you used? You spoke of making some modification of the hammer you first had. Did you have to use a special head?

Mr. Higgins. No. The principle of the head is the same, only we changed the length of the tool. The tools that we bought were long, and the calker discovered that it was much better where they were short, and we simply cut the tools in two and made two of them. In case of the 6-in. pipe, we narrowed down the tool a little.

We did not use the tool for putting in yarn, as we found it was cheaper to tuck it in by hand.

LOW CONSUMPTION OF WATER IN THE TOWN OF MILTON.

BY DAVID A. HEFFERNAN, SUPERINTENDENT OF WATER WORKS, MILTON, MASS.

[*Read September 11, 1914.*]

Milton is a town with a population of 8 470, lying between Quincy and Boston, and bordering on Canton and Hyde Park. It is supplied with water by the Metropolitan system, with two distinct services. The first, designated as the Southern High Service, accommodates about 83 per cent. of the consumers with a daily consumption of 285 000 gal., and has a pressure range of 30 to 110 lb. The remaining 17 per cent. is supplied by the Southern Extra High Service, with a daily consumption of 39 000 gal. and a pressure range of 50 to 133 lb.

On hearing this subject, the natural question is, "How does Milton maintain its low consumption of water, using as it does only 39 gal. per day per capita?"

To my mind, there are three principal reasons, which I will endeavor to explain from a practical viewpoint:

1. Universal meter system.
2. Our method of construction.
3. Rigorous control of hydrants.

Nothing else contributes quite so much to low consumption as a system universally metered. In Milton this is carried out to the highest degree. Not only are the private services metered, but in every municipal building, every standpipe, and every fountain, the water is being measured. Only hydrants escape this minute inspection.

No meter remains on a service for more than five consecutive years. At the end of that time, perhaps before, it is removed, cleaned, repaired, and tested in our own shop.

Meters are read twice every quarter by the inspectors, who carry aquaphones, always on the alert for foreign noises. If the

reading is larger than the average for that house, or a sound is heard which might possibly be a leak in the service pipe, a report is made to the office at the inspector's return.

Then a department plumber is sent to inspect the premises. Should he find the leak to be on the pressure side of the meter, it is repaired immediately by the department at the expense of the owner. If the leak is discovered on the house side of the meter, the owner is notified and his own plumber makes the necessary repairs. In this manner water department and consumer unite in reducing water waste to a minimum.

Another important reason is that the department does all its own work, main construction, services, and repairs.

Our system consists of 49 miles of cast-iron pipe, ranging in size from 4 in. to 16 in., the system being controlled by 576 stop gates; 364 hydrants take care of the fire needs, while the watering-carts may be supplied from 58 standpipes.

1 678 services furnish the inhabitants with water. Our own employees lay the service pipe at a stated cost per running foot, and it extends to the inside of the cellar wall where the meter is set. The responsibility of the department ceases at the meter, which is supplied up to $\frac{3}{4}$ in. without cost to the consumer. Should the applicant for water desire to lay the service pipe himself, or otherwise than by the town, the department will make the tap, and lay the pipe to a point just inside the property line, build a manhole, set the meter, and let him complete the service. However, this choice is very rarely taken advantage of, for the reason that if a leak should occur between the meter and the house, the department would have nothing to do with its repairing. And it has been found that contractors do not use the care in laying the pipe that the department does. Thus, the town, having complete jurisdiction over all the work it does, and over none other, and using only the best materials in this work, is in a better position to prevent unnecessary waste through these channels.

All construction, service and main work is tested by water pressure before back-filling. On all 2-in. work and over, a testing plug, tapped to hold a shut-off, is inserted in the bell end of the pipe. By means of this tap in the plug, the trench may be puddled after it is seen that all joints are tight.

Hydrants used in the town are post hydrants of one type, and are uniform throughout, having a 5-in. gate opening and a 7-in. barrel. Gates on all hydrant branches save shutting down an entire section when repairs on one hydrant are needed. Only firemen are allowed to use hydrants, and then only in case of fire. If contractors need water in a place where no means of supply other than a hydrant is available, the department will send a man to furnish them with water, the contractor paying for the water used and the labor incurred in supplying it. Besides an annual inspection, hydrants are carefully examined after every fire to make certain there is no leakage.

I have tried to explain what makes our consumption so low, as simply and concisely as possible. Many will say, or, at least, think, that it is because Milton does not contain many factories. To refute this argument I have but to give a few figures:

The night consumption tends to bear out my statement. Here, too, the consumption is the lowest of any in the system. An average of only 10 gal. per capita is measured daily, between the hours of 1 and 4 A.M. Compare this with the average of 56 gal. for the district and you will see that our system is in good condition.

The total amount of water measured by the Metropolitan meters in Milton, for the year 1913, was 118 million gal. The registration by house meters was 96 million gal., showing a difference of 22 million gal., or 18 per cent. This is accounted for by flushing dead ends, water used at fires, and the under-registry of house meters. We are fast connecting up our dead ends, and, taking everything into consideration, Milton seems to be in a fair way to lower its already low consumption, of which its water department is so justly proud.

DISCUSSION.

VICE-PRESIDENT SULLIVAN. Mr. Heffernan has just read a paper to us that has shown us what is possible. Of course, we have all been striving to reduce the per capita consumption, and he has achieved remarkable results.

MR. W. A. HAWLEY. The percentage of water unaccounted

for which Mr. Heffernan gives as 18 per cent. is within a fraction of one per cent. of what we have on our plant at Wilkinsburg. We account for 82 per cent. of the water. That, however, is not making any allowance for water loss from leakage or the quantity of water used in washing the streets and flushing sewers taken from the hydrants, and that sort of thing. Our per capita consumption, domestic, based on the water actually measured by the meters, for the past year was between 23 and 24 gal. per capita. Including manufacturing uses, our per capita use is something less than 100 gal.

THE USE OF THE MAGNETIC DIPPING NEEDLE IN LOCATING SERVICE AND GATE BOXES.

BY EDWARD D. ELDREDGE, SUPERINTENDENT OF ONSET WATER COMPANY, ONSET, MASS.

[*Read September 11, 1914.*]

Many of our members are familiar with the use of the dip compass for finding hidden service and gate boxes. For those who have not yet made use of that convenient instrument, I will say a few words with reference to its value to the water-works superintendent. In new water systems, in our small but growing towns, there is frequent necessity of laying pipes in streets and private ways where the grade is not established, the boundary lines are crude or imperfect, and where later there may be considerable change as improvements are made and sidewalks constructed. Houses are often built in advance of such improvements, water supply is furnished, and the records of stop-box locations are not wholly satisfactory or the ties of gate boxes reliable. When a sidewalk is made, the grade is often raised a few inches, or low spots are leveled up, and unless the water-works man is at hand, or notified, the service box is subject to being buried, particularly if it were not in sight at the beginning of such work. Later, when it may become necessary to use such a box, it is of great assistance to be able to locate it exactly, particularly if the ground is frozen. This is the function of the dip compass, or "detector," which can be used with most satisfactory success when the box is covered not over 6 in. or 7 in., which will include most all cases.

The dip compass consists of a magnetized needle or pointer, mounted on a horizontal axis and free to revolve in a vertical plane, normally that of the magnetic meridian. The needle is accurately balanced for the latitude of the locality in which it is to be used, so it will assume a horizontal position when

held in a north and south line, and subject only to the earth's magnetic attraction.

A service or gate box is a sufficiently large mass to offer a strong attraction to the needle, particularly as they are set in a vertical position, which is the most favorable. If the detector is held as described, with the needle at rest on the north and south line, and moved carefully, to avoid oscillation, over the ground and as close as possible to it without touching, when within six or seven inches in any direction from the hidden stop box, the needle will begin to show a deflection or dip, and by following it up to the point of greatest dip, the exact location of the box is discovered. As magnetism, unlike electricity, is not insulated by any substance, the attraction is ever present through air, frozen earth, cement, stone, tar, or anything liable to be encountered.

In a case where a cement sidewalk five or six inches thick was laid over a stop box, the box was located exactly, although the deflection is not so decided and quickly recognized in such a case as when a lesser covering exists. The same process, of course, applies to the ordinary iron gate boxes in street mains, which, in some of our unfinished streets, are often covered three or four inches.

DISCUSSION.

Mr. Lewis M. Bancroft. Mr. President, I had a little experience in the use of this dipping needle. There was one occasion where a tar concrete sidewalk had been laid, covering up the service box; the needle indicated the location of the box. When we came to get through, we found it thirteen inches from the top of the concrete sidewalk to the top of the box. More recently we had an experience trying to find a box where a great amount of rubbish had been dumped over the box, which had been put in before the sidewalk had been graded. First we found a jack-knife; next we found an iron wedge about six inches long and perhaps an inch and a half square, and finally the box. We had another experience with a stone approximately eight inches long, four or five inches wide, and possibly three inches in depth. One end of that stone was magnetic enough to attract that needle. The other end of the stone would repel it.

MR. J. M. DIVEN. Mr. Chairman, we located a valve box which covered 14 in., which seems to be about the limit. I have been able to locate in one instance a curb box through a concrete sidewalk. I also had the experience of locating buried horseshoes, etc. At the same time it did save a heap of digging.

If the needle becomes demagnetized, it can be quickly remagnetized, and at slight cost. The speaker had trouble of this kind with his dipping needle compass, which was caused by hanging the instrument on a gas pipe. The constant contact with the iron sapped the magnetism from the needle. Since discovery of the cause of the trouble, the compass has been kept in a wooden drawer, protected from the influence of all iron, and no further trouble has been experienced.

MR. HERBERT E. BRYANT. I would like to ask if, in the judgment of Mr. Eldredge, the fact of indicator being kept in a pumping station run with electric power would affect the reliability of the instrument. Something has happened to mine, putting it out of commission, within a month!

MR. ELDREDGE. I should say, if a needle was subjected to magnetic influence, its polarity might be neutralized or possibly reversed. I think it should be kept away from any strong magnetic influence, the same as a compass.

MR. C. D. SHARPE. Mr. President, I have had some experience with the dip needle, and I find, to make the operation of that instrument of the most value, a pipe-finding machine should be used in connection with it. This will give you the line of the pipe, and then it is very easy to trace along that line and find your curb box without digging up tin cans and horseshoes and other things that have been mentioned.

Of course the pipe-finding apparatus costs quite a little, but any of you gentlemen that have used one I think will acknowledge that it will pay for itself, as time goes by. Of course, in cities like Boston and Worcester, where the grade is established and streets paved, you do not have that trouble, but in the country, even if you make very careful measurements, when you lay a service, or put in a curb box, as has been said, if the superintendent is not notified of change of grades, when he goes out to find the curb box again it is gone. The surroundings have

been changed and you are lost. You are in a place where you never were before. But with the pipe-finding machine and the dip needle you cannot go astray.

Just a few days ago I had occasion to dig up a service pipe, and, by the way, it was at my own house, and I had lost it. I was completely astray. It seems that the measurement as given was the total, and then the total was subdivided some other way. I don't know just how it came, but it was nowhere near where the pipe was. I was so sure that the pipe was where it was not that I dug first without putting the pipe-finding machine on to it, and when I discovered it was not there, I went to the office and got the machine and I located it exactly.

MR. CHARLES H. TUTTLE. We have had very good success in finding curb boxes with an ordinary compass. Perhaps the compass is not as strong as the detector, but we find it a very convenient thing to carry in the pocket. All our men carry a compass. We are also very careful to take angle measurements of corporation cocks on the main as well as service boxes. We try to get measurements from some permanent corner. If it is near the corner of a street, we usually get it from the curb line; if not, we get it from the corner of a house. By taking an angle and using a tape line, we usually locate them pretty quickly.

CARE OF GATES AND HYDRANTS.

BY PATRICK GEAR, SUPERINTENDENT OF WATER WORKS, HOLYOKE, MASS.

[*Read September 10, 1914.*]

Among the important things for a water department to consider — probably the most important to the superintendent — is the matter of gates, hydrants, and meters. The hydrants must always be in working condition for the fire department, since any loss of time in putting water on a fire at its start, due to defective or frozen hydrants, may be attended with serious results.

In our city we have an index card for each of our 700 hydrants, giving the location, make, date set, size, cost, repairs, and date of repairs. We allow no one except a member of the fire department to operate them. We have a man attend all fires day or night, to see that the hydrants are working all right and to render such assistance as he can should there be any trouble with them. After the fire is over he is required to inspect them and see that they are properly closed, and to file a report of the same on cards furnished him. We do not allow any other city department to operate the hydrant in any way for any purpose. Our employees attend to all the opening of hydrants for street or sewer flushing and for puddling, and we charge them only for the water they use. We charge contractors and builders one dollar a day for opening and shutting hydrants, in addition to the cost of water. To plumbers for flushing sewers, etc., we furnish a man and hose and charge $1.50 for his time and water.

About twice a year we flush all our mains by opening the hydrants, and any trouble experienced in any hydrant is reported and rectified. Besides this, our hydrant inspector makes a general inspection of all the hydrants each spring and fall and reports the condition of each hydrant as he finds it. For his convenience we have divided the city into four zones and furnished him with a loose-leaf card book.

During the winter special attention is paid to such hydrants as experience has proven are most apt to give trouble. The inspector takes with him a string to which a piece of lead is attached, which he drops into the hydrant to find out if there is any ice there. So that the string may not get caught in the barrel of the hydrant, he has an eye turned in a piece of wire which he puts into the nozzle and his lead drops without any trouble. In ordinary winters we have no trouble, but in severe ones an occasional hydrant may freeze. If our inspector finds ice in the barrel he thaws it out with hot water; if he finds water he pumps it out with a small hand pump he carries for that purpose, and then puts in salt to keep it from freezing. Knowing the depth of each hydrant, he opens certain ones which may not be deeply set, to see if the branch leading from the main is frozen. Should it prove to be frozen, we take out a 25 h.p. steam boiler, connect it with about 25 ft. of hose to a ¾-in. pipe, put steam down through the ground to the frozen pipes in holes two or three feet apart, until the ground is warm enough to thaw out the pipes.

Where our hydrants are set in wet ground, we plug the drip and pump the water out after the hydrant is used.

Whether it is good luck or good care that accounts for it, we never yet had a hydrant frozen when opened for a fire.

About every five years or so we paint our hydrants a bright red and the top a white bronze.

Where the operating nut and stuffing-box are not brass, the lubricating and packing should be carefully attended to, and we send an extra man with our inspector to do this, as he is not able to do it alone. Most of our trouble comes from the hydrants of older makes; there has been some improvement made in hydrants in the last twenty-five or thirty years, but there is room for more.

The importance of good gates is, I think, very fully realized by us all. They control the flow of water to the hydrant, to the meter, and to each of the various fixtures which from time to time have to be repaired or replaced. They ought therefore to be of the best material and of the best workmanship.

If you have to shut off water for any reason and your gates are not tight, you are in trouble; you have to go back another

block to shut off. If your gate leaks at the stuffing-box, you have to dig up the street to pack it; if you have a gate that closes so hard that you break the spindle, you have to dig it up and repair it, and after you clean out the rust and put in your spindle your gate is all right and practically as good as new; therefore I suggest that a gate would be longer free from rust and dirt and could be more easily taken apart and cleaned if it was constructed with a brass gland; brass-lined stuffing-box; top of gate brass lined where the shoulder of the spindle rests; brass bolts and nuts in the stuffing-box, and slotted for easy removal; the rings in the body to be set out one-half inch or more and have a space of one inch on the sides and two inches on the bottom, to keep the dirt away from the gate and rings. A gate so made ought to cost but little more than those at present on the market.

DISCUSSION.

THE PRESIDENT. We have listened to a remarkably interesting paper and I want to hear a lively discussion on it.

MR. J. M. DIVEN. Mr. President, Mr. Gear spoke of using salt in hydrants to prevent freezing. What was the effect of that on the valve or the valve casing?

MR. GEAR. The salt is placed in the hydrant temporarily, to hold over during the winter months. Salt has no effect on brass, nor on rubber, especially when the gate is shut. We have a few hydrants which give us trouble of this kind, and when the frost comes out of the ground, we repair them.

MR. DIVEN. The gentleman also spoke of thawing hydrants by steam. He said he had no more trouble with one so treated during the winter. I should think the hydrant would be more apt to freeze on account of the moisture and steam. I don't understand the theory of that.

MR. GEAR. Mr. President, we have had this machine for a number of years, and use it on service pipes and hydrant branches that are frozen. If a pipe was broken, or any cause required the digging up of the street, where this machine was used, you will find that the soil will remain warm for a week or more. Any pipe that was thawed out by this machine will not freeze for the remainder of the winter.

MR. DIVEN. The speaker can hardly understand the theory that ground thawed out by steam remains warm. One would think that the moisture from the condensed steam would cause it to freeze quickly, and harder than before. We all know that water that has been hot freezes more quickly than water of a naturally low temperature. The speaker had some trouble with some hydrant laterals, on an exposed situation, in the winter of 1903–04. They were frequently thawed by electricity, but almost immediately froze again. They were finally dug, using steam to thaw the ground, and packed with fresh horse manure. Comparatively warm water, that is, water much warmer than that taken from the ordinary taps, was drawn from the hydrant during the winter. The speaker has been informed that these hydrants have given no trouble since, the heat of the manure evidently lasting.

This question of digging up the valve to repack leads one to reflect whether it would not be best, on well-paved and important streets, to place the valves in brick, concrete, or cast-iron pits large enough to permit packing the valves. The first cost would be high, but future expenses and much annoyance would be saved.

When, on the first shut down, valves were found to leak, on account of mud or rubbish under the gates, it has been the speaker's practice to open one or more fire hydrants, or a flush valve, if available, in the district to be shut off, and partly open the leaking valve. By opening partly and closing a few times, the valve can usually be made tight. The rush of water at high velocity through the small opening washes the dirt from the seat ring.

The speaker can hardly agree with Mr. Gear in the matter of testing valves; they should be thoroughly and frequently tested, even to completely closing them where practicable. In no other way can one be sure that they will be tight when needed. With a nearby fire hydrant open, the aquaphone, water sonoscope, or similar instrument will tell if a closed valve on a line is tight. The speaker was put in charge of a water works that had neglected valve tests, and, on making an inspection and test of valves, found 244 out of about 1 100 in some way defective, needing packing, cleaning of boxes, and in many cases with broken stems, — any-

way, not in condition to give service if called upon. How long the valves had gone without testing, the speaker cannot say, but the condition found was certainly serious.

MR. GEAR. Mr. President, we have our men go around and try all valves, put the key on same, partly open and shut them, and if they should find any valve leaking, repair it. If the stuffing-box was properly constructed, there would not be any of this trouble caused from opening and closing of valve, or the leaking of same at the spindle.

MR. WM. C. LOUNSBURY. Do you use the same packing you buy with the valve, or do you take that out and repack it?

MR. GEAR. The packing sent with the valve is as good as any that can be bought. If it is not good packing, then let us insist upon them getting the very best there is, and may be this would overcome the replacing of the packing.

MR. LOUNSBURY. We have found it advisable to remove the packing that goes with the gate and put into the stuffing-box carefully prepared packing which we lubricate ourselves.

I would like to ask how often in winter you inspect fire hydrants in regard to freezing, — whether you make a daily inspection or not in cold weather.

MR. GEAR. Knowing the hydrants which cause us the most trouble in the winter time, we make a daily inspection of them. If our inspector should find them all right to-day, he may skip to-morrow's inspection, but you may rest assured that he will keep close tabs on them. I want to say that up in our city we all die on the job, because no one ever resigns or is discharged, so you see that we ought to know the pedigree of every hydrant.

MR. LOUNSBURY. I represent Superior, Wis., and unless somebody contradicts me I am going to claim the long-distance record. I came 1 505 miles to this meeting. We have a somewhat colder climate than they used to have here in Boston. I understand now from experience last winter that you are trying to take the record away from Northern Wisconsin. But we have seen more than 40 below, and it is often 30 below. Of course we pay particular attention to freezing, and we have a record which is like Mr. Gear's; it may be either through good inspection or through pot luck, but we have never had a hydrant frozen when the

department wanted to use it, although we have had a great many hydrants frozen which the inspectors have found. Now we find it is necessary to keep a crew of three men through the winter working on the hydrants, testing them, in much the same manner as was told, with a lead sinker on the end of a cord. The hydrants which we find frozen are those which the contractors and others beside the fire and water departments have used during the year.

Now, about salt. We represent in Superior the Water Company; the Gas Company is the same corporation, and I might say that I also represent a private corporation. When the gas services freeze, the common practice is to pump wood alcohol into the service. It clears it out. Now you all know, I presume, that alcohol is good to keep the radiators of automobiles from freezing, and if they do freeze, instead of having ice that expands and breaks the radiator, it makes a kind of mush. When we find a frozen hydrant, we thaw it out with our steam boiler and then give it a good liberal dose of alcohol. We put in a pint or sometimes a quart of wood or denatured alcohol. We use wood alcohol because we have found it a little more efficient. Slush may form around the valve, but nevertheless you are able to turn the stem and open the valve. I think that where you can use it, alcohol is very much better than salt.

The matter of having the contractors and the other city departments use hydrants is a matter of very great importance to water-works superintendents. It is a matter which we have found in the Middle West very hard to control. Particularly in a rapidly growing new city there is a great deal of contract work to be done. A great deal of street paving must be put in, and it seems to be a hardship on the contractors to make them use house services for their work. As it does not seem feasible for the water department to furnish a man to stay with the hydrant, we require all contractors to take a meter from our meter department, making a deposit of $25, which is returned to him when he returns the meter, and after our inspector has seen that the hydrant is in good shape. That gives us some hold on the contractor. In addition to that, we bill him for water at the regular rates, but the actual amount of water used on such work is so

small that the price we get for the water is immaterial. The reason we want the meter there is to have some hold upon the contractor. The fire chief objects to the indiscriminate use of the hydrants, and has reported to the commissioners annually that the contractors should not be allowed to use the fire hydrants. But it seems to be at least the line of least resistance to permit them to continue to use them.

Then, again, there is the matter of the street watering. I do not know what the Eastern practice is, but in some of the cities valves have been tried on the hose connection of the hydrant, but that does not always work well. We have a great many leaking hydrants because somebody that drives the watering-cart starts to open the hydrant by turning it the wrong way, or does not know when he gets it open.

The matter of sewer flushing causes us a good deal of friction. There, again, it seems that we must permit the head of the sewer department or the sewer foreman to open the hydrants. This is a matter that causes us a great deal of annoyance because Superior has a direct pumping system. When the hydrant is opened suddenly on such a system it may cause a considerable amount of inconvenience. We try to control this by having the foreman call up the station before he opens up a hydrant. We have had our crew out looking for a break or leak only to find the next day that they had two hydrants opened at once and were using water pretty liberally through fire hose with no proper nozzles.

I presume this matter of the alcohol is more or less familiar to you and I would be pleased to know whether that is a common practice through the country or something which is a local condition with us.

Mr. John Doyle. I have been much interested in the paper read by Mr. Gear, as we in Worcester pay especial attention to the care of our hydrants. In the first place, both the street, sewer, and forestry departments are generally permitted to have the privilege of opening all hydrants for construction purposes, the forestry department particularly for spraying purposes. Now we have a form of permit which is issued to all those different departments which they are supposed to return to the water

commissioner within twenty-four hours of the time a hydrant has been opened. We immediately have a man sent out and inspect such hydrants, his time being charged up to the department using them. Now, as you all know, hydrants under such conditions are opened by men who have had no experience whatsoever in opening hydrants. Sometimes you will see a foreman working on a construction job. And often he will send the rawest laborer he has got at work to open the hydrant, and we have to give them further attention. Now, if the inspector finds there is anything the matter with the hydrant, we immediately fix that and charge the cost up to the department which caused it. We employ two men doing nothing else but looking after hydrants. We have about 2 300 fire hydrants that belong to the city, and 234 to individuals and corporations, which we do not attend to unless called upon, and then any repairs are charged up to the individual.

In cold weather, particularly along about the latter part of October or the first of November, we send out and make a preliminary inspection of all the hydrants. As soon as the weather becomes very cold, — possibly along about the middle of December, sometimes earlier, — we start our winter inspection. We have the city divided into five districts and each district divided into four routes, with the exception of District No. 1, comprising the center of the city, which has a total of about 225 hydrants, and is divided into two routes. District No. 1 is covered every other day by one man. The other routes, being on the outlying districts, further away, are covered by two men to each route, covering each district once in four days. Those men carry an iron kettle and a water pail. Sometimes there is salt in the water pail. They work in close touch with one another so that if they should happen to find anything the matter with a hydrant, holding water or skimmed over with a little ice, they go to the nearest house and borrow a kettle of hot water, and if they can overcome the trouble, all right. If the hydrant does not drain, they immediately notify the shop and we send out men to take care of the hydrant. We make a close inspection of all hydrants after a fire.

Now there are eleven men doing nothing else in the winter time

but inspecting hydrants, and those men are generally men whom we employ during the summer months with other work. We have to keep them anyway, and we find that winter employment for them.

As to the method of keeping hydrants from freezing, we have used salt and are now using denatured alcohol with great success, and I find good results from it.

As to the care of water gates and valves, during the winter months we inspect all valves and shut-offs. The men employed on that work are also men whom we employ steadily during the winter months and with other work in the summer time. We have the city divided into districts and routes, and a record is kept of all inspection on a card system. I might also add that for hydrant inspection we have a card system with the inspector's name, the date of inspection, and the condition in which the hydrant was found. We partially close and open all gate valves and see that they are in working condition, and that the boxes are cleaned.

MR. THEODORE MCKENZIE. I would like to ask Mr. Gear how he manages the firemen opening and closing hydrants for purposes of trying the hydrants and throwing fire streams, whether for pleasure, profit, or necessity. I have been troubled a great deal by firemen going out at any time, night or day, summer or winter, and opening hydrants for trial purposes and stirring the water all up. You can't open a hydrant anywhere without getting bad water, and then you have got to go over the whole system to clean it up.

MR. GEAR. We do not have any trouble with the firemen, and they notify us whenever any hydrants are to be opened for trial purposes. Our inspector is there at all times to see that the hydrants are shut down properly, and if he finds any out of order, he files a report to the superintendent.

I heartily agree with Mr. Lounsbury when he says that alcohol is very useful for hydrants.

MR. C. DWIGHT SHARPE. These gentlemen, who have spoken on the care of gates and hydrants, fortunately belong to cities large enough to allow keeping a gang all the time. I happen to represent a small water works in Putnam, Conn., where the

superintendent is the captain and the crew and boatswain's mate, — and the cook stays in the house where I live. If we had men at liberty or where we could call upon them to do these several things that these gentlemen have said, we could be out of some of our troubles, but unfortunately, the superintendent is called upon to do most of these things, and sometimes in the middle of the night, after being tired, he does not wake up when the fire bells ring and he does not get there.

I am very tender about trying to tell a country fireman how he should open a hydrant, because you fellows that belong in the country, where they have volunteer firemen, know that if you get in bad with the firemen you might as well throw up your job. We do have trouble with our firemen in opening hydrants, and even when some city departments have visited us and our hydrants happened to open the other way, they were bound they should open the same way theirs did, and they put the force to it and consequently put the hydrant out of business. If any one present can tell me a way to get ordinary intelligence into a country fireman about opening a hydrant, I would like the receipt.

In our hydrants, the stuffing-box and gland and spindle are all brass, so we have no trouble with the turning of them ordinarily. A short time ago we had a serious fire about two o'clock in the afternoon with the thermometer six degrees below zero, and at two o'clock the next morning the fire didn't seem to be put out thoroughly, and we had another alarm and the same hydrants had to be used again, and they couldn't open one of them. The hydrant was dry, but the stuffing in the gland had frozen on to the spindle, and we couldn't open it until we brought a blow-torch and warmed it up. That came back on the superintendent, of course, because he was the man who ought to have seen that they were right, and stayed out there with a blow-torch all night.

Now as to the packing for gates and hydrants, I have found very good success with a spindle packing made up with some grease and plumbago. I have had no trouble with it whatever and it holds very nicely. I have had trouble with the flax packing coming out.

The matter of hydrants freezing has been mentioned here, and a gentleman beside me said that where ground was frozen and

thawed out it would freeze all the quicker. Now, that has not been my experience. I have always found that where we have had trouble with our service or with hydrant branches, the fall before has been a very dry one, and if we can get the ground full of water late in the fall, we will have no trouble. I do not know how you can explain it, but I explain it in this way, that the moisture in the ground eats up the frost or keeps it from going down so low. I know it has been my experience that with dry ground, frost will go deeper than with wet ground. That may be new to some of you, but I found it so many times.

In regard to the use of hydrants by contractors, of course this could not be done as I have done it, in a large city, I suppose, but where contractors have wanted to use water for building purposes or road purposes it has been my plan to turn the water on to the main hydrant and then put a cap on with the proper valve so that they can control that valve, instead of opening and closing the hydrant every time they wanted to use it.

MR. LOUNSBURY. Do you leave that on over-night?

MR. SHARPE. Yes; of course, as I say, it is a country town, and the firemen would find out that the water was on, immediately they put the wrench on the cap to take it off, and it would take only an instant to close it. Three turns and the valve would open enough to get by the waste.

Our hydrants are the Coffin hydrant with the metal disk and metal valve, and are all leaded on. If any of you have ever tried to repair a hydrant where the seat has been scratched, with the hydrants leaded on, and in positions where you couldn't melt out the joints, you know how difficult it is to face up the seat, and then face the valve to fit it. That is the difficulty that I am in, and while I have had very good success in doing that in the past, I may fail sometime. But it certainly is a task to do it, and it takes nearly half a day to face up a seat and then face the valve to fit it. With bolted flange hydrants it is easy to replace the hydrant and send the injured one to the shop for repairs.

MR. GEAR. In regard to hydrants that freeze after a fire, so that they could not be opened, I would say that they were frozen at the stuffing-box. The same condition is to be found in the old-style hydrant, with iron rod attached and where rust forms in

stuffing-box, even in the summer months. I suggest that you take a hammer, hit the top of the operating rod, and break the frost or rust, whichever it may be; you will readily see that the hydrant can be opened easily.

MR. ROBERT S. WESTON. I would like to ask if any of the gentlemen have ever used crude glycerine in the hydrants in place of salt or alcohol? It is used a great deal in automobile radiators and in many industrial plants to prevent freezing. It costs about eighty cents a gallon, I think, and will go a great deal farther than alcohol.

MR. J. M. DIVEN. I have used it with great success. It doesn't evaporate. It lasts longer.

Mr. W. C. HAWLEY. I am very glad that municipal plants are beginning to take the position that no one but the water and fire departments should operate the hydrants. I have been up against that proposition for a good many years, and within the last two or three years in making new municipal contracts — I represent a private water company — we have taken the position that the fire hydrants should not be used for any other purpose but fire protection and for street washing and sewer flushing, and then they are to be operated by an employee of the water department. That has been incorporated in our new contracts, and those contracts have been approved by the public service commission of the state of Pennsylvania.

We have one little wrinkle in the testing of our hydrants. We test them three times a year. We have very high pressures, and if we open the hydrant fully and then turn it down again, the street will be flooded or water will be thrown clear across the street. And to obviate that we use a hose valve, put the hose valve on, close it and open the hydrant fully, so as to be sure that it is operating properly; open the hose valve enough to blow out enough water to clean the hydrant. We find that saves the valve a good deal. Otherwise the valve is merely opened, the valve started from the seat, and any foreign matter catches between the seat and the valve, and with some of the hydrants that means repairs. We do not assume all the responsibility for testing the hydrants. We insist on the representative of the municipality — generally the chief of the fire department or someone

assigned by him — going with our assistant and keeping his own record of the test. Then if something happens we have more than the mere word of our own inspector.

As to the care of the valves, I have found that in some mysterious manner valves will get closed. I know of one case where a 16-in. gate had been closed while some repairs were being made, and the foreman took one of his men and started to open that gate and opened it enough so that one man could continue the operation, and left a man to do it. He opened the gate for a while, got tired, sat down and rested, got up, supposed he was opening it, and instead of that closed it. We didn't know that gate was closed until there was a fire. I found on making inspections of a large mileage of pipes a number of gates closed that were supposed to be open. Therefore we have adopted a plan of a report of the foreman or his assistant of every gate that he operates, the reason why it was operated, the time it was closed, and the time it was opened. In that way we try to keep track of just what happens. We make an annual test of all the gates, open them and close them, and in that way we are sometimes surprised to find gates out of order that so far as we knew were all right, with broken stems and other things that would put the gate entirely out of commission if we wanted to use it. We also operate our gates quite frequently in making tests of our distribution system, and that enables us to keep track of the condition of the gates. Under pavements we have been using concrete boxes of pyramidal shape, reinforced concrete slabs put together so that if the valve needs it a man can get down and pack it without digging it up. The boxes are expensive as a matter of first cost, but very much cheaper than having to dig up your valves two or three times.

I should like to ask the gentleman from Wisconsin how much alcohol he uses to a hydrant in order to prevent it from freezing.

MR. LOUNSBURY. This alcohol doesn't prevent the water entirely from freezing. It freezes in a kind of mush that does not stick. We put in from a pint to a quart into the barrel. Of course those hydrants are particularly well guarded because if you go back it might test and seem to be free.

MR. CALEB M. SAVILLE. May I inquire of Mr. Hawley what is the cost of the concrete box that he speaks of?

MR. HAWLEY. I can't tell you exactly what the cost is. We have the material at the yard, and it is a rainy-day job for the men. If they have any spare time they make up a few, and the first time we have to repair a valve the box is set. It is a matter of, I suppose, twelve or fifteen dollars.

MR. SAVILLE. I had rather occasion to look that up a short time ago, and I inquired of the water company in Connecticut that included that pyramidal shape that you speak of. I understood them to tell me that they cost something less than five dollars.

MR. HAWLEY. They cost me more than that.

MR. SAVILLE. These were meter boxes, however, that they put in.

MR. HAWLEY. These go out in the street, of course, and require a heavy cast-iron cover.

MR. SAVILLE. These were a light cover such as would be on the meter box. I imagine the four sides to make the pyramid would be about the same. These that I saw at that time were about two feet wide at the top, perhaps, and perhaps eight feet at the bottom, and beveled so that all four would come together and the box fit on top, about three inches thick, and would cost something about five dollars.

MR. DANIEL A. MCCRUDDEN. Mr. President, in Philadelphia they use a concrete box of an elliptical shape, the material for which costs about four and one-half cents, and the labor cost of making them would be four cents an inch in height. We use slabs 4 in., 6 in., and 12 in. high, one on top of the other. The frame and cover costs about $6.75, the labor in putting in the box and removing the surplus dirt costs about $4.50, making a total cost of $13.00 to $15.00 to replace a wooden box with a permanent concrete box. The cost of repairs is practically nothing.

They are 2 ft. by 2 ft. The top has a 2-ft. circular opening in the elliptical form; it is reinforced with ½-in. iron rods and made to fit our standard frame and cover. This rests right on the elliptical slabs, and the frame and cover, which is 2 ft. inside diameter, rests on the top slab. In this box we can always get to the valve to pack it, no matter how deep; in fact, you can place a valve in the box without digging up by using what we call an

extension sleeve, a casting which I do not think the New England Water Works Association recognizes as a standard casting.

MR. P. R. SANDERS. Mr. President, Mr. Hawley's speaking of finding gates closed mysteriously once in a while reminds me that we have to be very careful on our large 20-in. and 24-in. gates when the men operate them. Of course some of our gates are geared to an upright. They put the key on a small gear and work that awhile. They find it goes easy and they think they have got it about half open. They then will go to work on the big one and turn that in the same way. Instead of opening or closing the gate, they are just shutting it right down again. Just last month we had a large leak, a hydrant blew off from a 10-in. line right on to a 20-in. line; there was about 28 lb. pressure. When we wanted to let the water back again these men went to work on the gate to open it up. They started turning to the right, as we open our gates. It went easy, and they put the key on the center spindle and kept turning the gate the same way. Come to find out, they kept closing the gate down again. If I hadn't been on to it, it would have been closed.

MR. J. M. DIVEN. I was going to say that when hydrant trouble has been neglected, I think it is caused by the use of Stillson wrenches operated by contractors and others. Possibly somebody else has had trouble with that.

THE PRESIDENT. We have suffered greatly.

MR. HERBERT E. BRYANT. I want to ask if there is any demand for such a thing as a faucet seal. I represent Kingston, Mass. There we collect our water tax by fixtures rates in every instance, and we find great difficulty in determining the number of faucets in the house, or any place where they are used, that are in actual use. Some people swear they are not using certain faucets and sill cocks, and in the course of a week or a month you will find they are. Then there are the really honest people that don't use them, that have great difficulty in presenting an argument to assure you that they are not bluffing you. So we have got around that question there by adopting a seal and including in our rules that all faucets that are not sealed shall come under the fixed rate, the water department standing the cost of the seal

and the placing and displacing of the seal. So far we have found, that assists us greatly in the case of vacating tenants. They are very ready to tell us when tenements are vacated, but there have been only one or two instances in which they were in any hurry to tell us about the premises being reoccupied. So it seems that the only thing we could do, to do away with the embarrassments on both sides, was to seal those faucets. Now we have got a very simple device for a seal, and what I really want to find out is if there is any demand for such a thing elsewhere. The first part of seal is nothing but a screw shell that turns on by hand and puts the faucet really out of commission. And the next is a cover, to prevent taking the cap off. This is a copper shell with upward extended lugs, which is turned down over the flange of the faucet, then brought up tight with a wire and seal. Now if there is a requirement for such a thing, I would like to have the different representatives of the water departments leave their names with me or at the desk, and as soon as we get a quantity of them I would be glad to send you a sample and any written instructions that may be necessary. I may state further, that I will leave this on the desk for anybody who cares to look it over.

Mr. Frank J. Gifford (*by letter*). In regard to inspection of hydrants in severe cold weather, I would say that in Fall River we inspect hydrants in the congested value district every day, and in the residential and outlying districts every other day.

In reply to the gentleman from Superior, I would say that I have been using denatured alcohol in hydrants about three years, and find that it gives good satisfaction. Several cases I have in mind where ground water was in the hydrant, and which was treated with alcohol, gave us no trouble during the entire winter.

The alcohol works very well when ground water alone is present, but if a slight leak develops on the valve, the mixture is forced into the head of the hydrant and remains liquid, while the water underneath freezes solid. This condition we find when the cap is removed from the steamer connection, the mixture running out of the hydrant freely.

In speaking of a slight leak developing on the valve, I find that this condition occurs during extremely cold weather; our inspector finds a hydrant perfectly dry when he makes his inspec-

tion; two days after, on the next inspection, he has trouble in taking the cap off. After removing cap, he finds the hydrant solid to the head with ice.

Mention was made of stepping into a nearby house and getting a kettle of hot water to thaw hydrants. This method we used to use until the inspectors began to complain of the nuisance it caused people and of the many refusals they had. Each inspector now carries, beside his pump and hydrant wrench, about half a pail of lumps of quick lime. When he finds a hydrant with ice in, due to ground water, he puts in two or three lumps of lime and perhaps a little cold water, puts on the cap and continues his inspection, returns in about half an hour, and is able to open the hydrant and flush out the lime and pump out the barrel. This hydrant is reported to the shop and is then treated to a dose of alcohol.

ALLOWABLE LEAKAGE FROM WATER MAINS.

BY E. G. BRADBURY, COLUMBUS, OHIO.

[*Read September 9, 1914.*]

It is not the purpose of this paper to discuss at length the miscellaneous losses of water from existing pipe systems, but rather to consider the reasonable standard of workmanship in the laying of new pipe.

Numerous investigations conducted within the past few years have shown enormous losses by leakage and carelessness. The fact that willful waste and defective plumbing are responsible for the major part of such losses, and are, moreover, more easily located and stopped, has resulted in greater attention being paid to them than to the leakage occurring underground, although considerable work has been done in the way of discovering and correcting large breaks.

It is well known that the water unaccounted for in the average system ranges from 20 to 60 per cent., and published records of measured leakage vary from 2 000 to 200 000 gal. per mile of pipe daily. In many of the water-waste survey reports, underground leakage and the losses through unmetered services and sprinkler systems are combined as a single item. The Bureau of Economy and Efficiency in Milwaukee finds that about 23 per cent. of the total pumpage is lost in this manner. The New York reports refer to joint leakage as "relatively small," while showing that underground losses of various kinds reach a very large figure. Mr. Phillips places the underground leakage and willful waste at 57 per cent. of the total amount of water unaccounted for in Chicago. The city of Washington presents the only evidence in the hands of the writer indicative of the relative proportion of main joint leakage, the reports of the engineer department of the District of Columbia containing figures showing that such leakage averages approximately 23 per cent. of the entire amount of water lost beneath the ground surface.

TABLE SHOWING PROPORTION OF MAIN JOINT LEAKAGE DETECTED AT WASHINGTON, D. C., COMPARED WITH TOTAL UNDERGROUND LEAKAGE.

Year.	Total Underground Leakage. Gal. per Day.	From Joints in Mains. Gal. per Day.	Per Cent.
1908.....	4 243 900	1 013 900	24
1909.....	6 657 635	1 345 620	20.2
1910.....	6 364 000	1 034 000	16.2
1911.....	6 921 916	2 562 461	37.1
1912.....	5 115 320	746 305	14.6
1913.....	4 196 070	962 310	23
Average.....			23

The records of fully metered cities and the results of water-waste surveys prove that, although possible, it is the rare exception when underground leakage is kept down to a low figure. Very few cities keep such loss below 3 000 to 5 000 gal. per mile daily, and many very greatly exceed these figures. Mr. Kuichling, in a paper before the American Society of Civil Engineers (Transactions, Vol. 38), set the familiar standard of one drop per second from each joint, five drops from each hydrant or stop valve, and three drops from each service pipe as a fair average in a well-constructed system, resulting in a total of 2 500 to 3 000 gal. per mile daily.

Main joint leakage is so distributed, except in case of an occasional blow-out, as to make repairs more expensive than can be justified by the saving accomplished, and yet may in the aggregate result in serious losses. This fact imposes on the builder of water lines the duty of exercising every reasonable precaution to insure the tightest possible work. Pipe systems necessarily deteriorate more or less from year to year, but carelessly made joints must be more likely to loosen than thorough and painstaking work, and the ratio of loss between tight and slovenly work will at least not decrease with age.

Statements of leakage in terms of percentage of total water pumped, or gallons per capita, mean very little. The only rational unit is one which takes into consideration length and size of pipe; the writer prefers the number of gallons daily per mile for each inch of diameter, expressed as " gallons daily per inch-

mile." "Gallons daily per foot of lead joint" is an equally rational unit — in fact, slightly more so — but is less convenient, especially if used with exactness. The length of lead joint per inch-mile is about 120 ft.

The practice of applying a test of some character to newly laid pipe is probably general at the present time. This test should preferably be made in the open trench, examining all joints under pressure before covering, but if the pipe is necessarily covered before testing, a maximum allowable leakage per inch-mile should be specified and rigidly enforced.

By the method of open-trench inspection it is possible to make a new system practically bottle-tight. The measured leakage in 5.5 miles of 6 to 12 in. pipe laid and thus tested by the writer at Grandview Heights, a suburb of Columbus, Ohio, amounted to 2.3 gal. per mile daily, or 0.31 gal. per inch-mile. This system is supplied through a meter from the city of Columbus, and every service is metered. The actual amount of water entering the mains in the 2.5 years since its installation was 2 104 000 cu. ft., according to bills rendered. The quantity sold through individual meters for the same period was 1 998 600 cu. ft., and about 30 000 cu. ft. was used in flushing sewer trenches. In addition to this, contractors for several macadam streets were permitted to use water without measurement. Even without making any allowance for this last item, nor for the fact that nearly a mile of extensions have been laid during the period, it will be seen that the water unaccounted for amounts to less than 20 gal. per inch-mile daily.

In the opinion of the writer, the inconvenience to which the public is necessarily subjected by this method of testing is well justified by the certainty of results and the perpetual saving accomplished, except in the busy streets of the downtown district in cities of considerable size. Where the demands of traffic are such that it is absolutely impossible to hold the trenches open, the specified leakage test must be substituted. In designing the extensive improvements to the water works of the city of Akron, Ohio, Mr. F. A. Barbour and the writer specified, after much consideration, a maximum permissible leakage of 200 gal. per inch-mile daily — equivalent to about 1.6 gal. per foot of lead joint.

The pipe laid at Akron comprises new supply lines, lines paralleling and reinforcing old mains of insufficient capacity, and extensions into streets not heretofore furnished with water. The new supply lines and reinforcing mains are laid by contract under the supervision of the designing engineers, Mr. E. A. Kemmler, department engineer, being in immediate charge, while the extensions are laid by employees of the city, under Mr. H. H. Frost, superintendent of water works. All pipe is purchased by contract and is inspected at the foundry by experienced men. The depth of lead specified is $2\frac{1}{4}$ in.

The method used in all tests was as follows: After completion of laying, the pipe was filled with water and usually allowed to stand for about twenty-four hours, to permit the yarn in the joints to become saturated. The pipe having been tapped for a $\frac{3}{4}$-in. connection, a small hand-pump was connected by wrought-iron pipe and fittings, on which a gage was set, the suction being placed in a barrel of water. All gates were then closed and a hydrant valve opened to determine whether gate leakage existed in amount sufficient to flow. The depth of water in the barrel and its diameter at water level were then measured, and pumping begun. If the pressure was readily raised to the required amount, the time was noted and the amount of water required to hold the gage stationary for a period of from ten to thirty minutes carefully observed. The leakage was computed from the quantity so used. If too great difficulty was found in raising the pressure, or if the leakage was found to exceed the allowed quantity, pumping was stopped and the gage observed to see if it would remain stationary after dropping to city pressure, thus indicating gate leakage; if such leakage was not demonstrated, effort was made to find defects in the pipe. In one or two instances pipe which could not be pumped up to pressure on the first trial were successfully tested on the following day, no satisfactory explanation being found. In a considerable number of cases the contractor was required to locate leaks and recalk joints, sometimes causing the reopening of the trench for considerable distances. In two cases cracked pipe was located and removed.

The final results of the tests have been very gratifying. One hundred tests have been made of pipe laid by contract, of which

86 are included in the summary given below. Of the remaining 14, there were 8 in which all joints were visible and no leakage existed, but on account of loss through gates no measurement was made; 3 in which the measured loss somewhat exceeded the specified maximum, but evidence of gate leakage was such as to satisfy the engineers that the specifications were complied with; and 3 in which the leakage was above the specified amount and the work not accepted. Of 40 tests made by the superintendent of water works, of pipe laid by his department employees, 38

TABLE SHOWING SUMMARIZED RESULT OF 86 TESTS OF PIPE LAID BY CONTRACT, AKRON, OHIO.

Size, In.	Length, Ft.	Leakage in Gallons Daily per Inch-Mile.	Number of Tests.
4	717	23	1
6	31 066	66	34
8	6 882	42	6
10	5 123	81	5
12	9 704	102	8
16	8 792	135	11
20	8 389	69	10
24	3 358	69	3
30	14 445	82	8
	88 476	83.4	86
	16.76 miles		

Pressure from 66 to 152 lb., — 35 lb. greater than static head when improvements are complete.

TABLE SHOWING SUMMARIZED RESULT OF 38 TESTS OF PIPE LAID BY SUPERINTENDENT OF WATER WORKS, AKRON, OHIO.

Size, In.	Length, Ft.	Leakage in Gallons Daily per Inch-Mile.	Number of Tests.
6	37 524	59	32
8	6 509	63	5
10	2 850	133	1
	46 883	61.7	38
	8.9 miles		

have been tabulated, the remaining 2 exceeding the permissible loss; these are to be dug up if necessary, to locate and repair the leaks.

It is to be noted that all the above figures are probably high, as they include whatever leakage may have occurred through gates as well as actual loss. Such leakage was known to exist in many cases, and in 20 of the tests of pipe laid by contract and included in the above summary every joint was visible and tight, although usually some water was required to keep up the pressure. The amount pumped also covers any contraction or absorption of air contained in the pipe. The presence of any considerable amount of air makes the tests unsatisfactory, and occasionally it becomes necessary to tap the pipe to release it.

Check tests made several months after the original test in two districts of about one mile each, of 24- and 30-in. pipe, verified closely the previous work, showing losses of 55 and 79 gal. per inch-mile respectively.

The results of the Akron tests are considerably below the requirements of many engineers. Mr. W. D. Gerber, in a paper read before the Illinois Water Supply Association in 1913, mentions 167 gal. per inch-mile as the usual allowance. The New York Aqueduct specifications allow 2 gal. per foot of lead joint, equivalent to about 240 gal. per inch-mile. Mr. J. H. Gregory specified permissible leakage at Columbus equivalent to 507 gal. per inch-mile on 20-in. pipe, and 528 gal. on 24- and 30-in. pipe,— all under about 110 lb. pressure, and contributed an article to the *Engineering Record* of April 20, 1912, justifying this specification, with the statement that "the limits of allowable leakage specified were not guessed at, but were determined after a careful study of the measured leakage in pipe lines with which the writer was familiar," and showing that the actual leakage in the pipe laid under these specifications ranged from 71 to 103 per cent. of the amount permitted. This article was in reply to a suggestion contained in a paper read by the writer at the 1912 convention of the Ohio Engineering Society, in which leakage in general was discussed, that Mr. Gregory's specifications "leaned far toward liberality."

Assuming the average diameter of pipe in a complete system to

be 9 in., each 100 gal. daily per inch-mile saved or lost has a value of $3.28 per year for each mile of pipe at a production cost of $10 per million gallons, or, capitalized at 7 per cent., is worth $46.86. Applying these figures to a concrete example, a city of 100 000 population with a production cost of $25 per million gallons, and 160 miles of mains, would gain $5 256 per year by a saving of 400 gal. per inch-mile; and, figuring interest and sinking fund at 7 per cent., could afford to have spent $75 000, or about $470 per mile, more on construction to accomplish this result, and the same amount lost per inch-mile would cost a city of 200 000 population with 300 miles of mains and a production cost of $50 per million gal., $19 700 per year — equal to an investment of $281 430.

The expense of testing in the manner described is not heavy, averaging about $50 per mile. Occasionally where careless work has been done and the pipe covered, the contractor foots a rather heavy bill of expense; but the knowledge that the work is to be tested discourages carelessness, and most of the tests are made quickly and without trouble.

The writer believes that the results at Akron are as good as can usually be obtained under practical conditions. Many years ago Mr. C. F. Loweth stated before the American Society of Civil Engineers that he had satisfied himself of the possibility of laying water pipe with a leakage not exceeding 60 to 80 gal. per inch-mile daily. This is borne out by the data given above. It is apparent that to go farther than this in a specification is not safe, on account of gate leakage and other internal conditions.

In view of all the above facts, the writer proposes as a standard for allowable leakage in new cast-iron water pipe an average of 100 gal. daily per mile per inch of diameter for each complete contract or district, with a maximum limit of 200 gal. daily per mile per inch of diameter not to be exceeded in any single test. The recommendation is made, however, that open-trench testing, with all joints visible, be specified, covering being done only by special order, and the allowable leakage clause used only when it is entirely impracticable to keep the ground open.

TABLE I.

TESTS OF PIPE LAID BY CONTRACT, AKRON, OHIO.

Street.	Length, Ft.	Size, In.	Test Pres. Lb.	Leakage, Gallons per Day per Inch-Mile.	Remarks.
Turner	663	6	150	128	All joints seen.
Turner	599	6	150	157	All joints seen.
High	661	20			
	37	16	136	179	All joints visible.
	33	6			
High	629	20			
	40	16	120	55	All joints visible.
	103	6			
High	751	20			
	13	12	120	0	
	15	6			
May	1 262	6	120	75	
Yale	1 130	6	125	56	
	18	4			
Grand	475	6	90	104	All joints visible.
High	824	20			
	15	16	128	20	All joints visible.
	20	6			
Thornton	514	16	120	39	All joints visible.
	17	6			
Iron	478	16	140	80	
E. Market	545	30			
	15	24	122	67	
	6	8			
	54	6			
E. Market	1 867	30	105	27	
	63	6			
Steese	361	16	125	59	
	4	6			
Chestnut	365	16	150	68	
	4	6			
Exchange	949	20	115	2½	
	23	6			
Exchange	920	20			
	19	8	108	16	
	50	6			
	40	4			
Exchange	1 145	20	90	162	Trench partly filled.
	4	6			
Exchange	930	20	105	100	
	60	6			
Exchange	1 037	24	104	105	
	65	6			
E. Market	1 634	30			
	24	10	107	96	
	41	6			
High	393	20			
	23	8	132	32	
	7	6			

TABLE I.—*Continued.*

Street.	Length, Ft.	Size, In.	Test Pres. Lb.	Leakage, Gallons per Day per Inch-Mile.	Remarks.
E. Market.....	1 278	16			
	40	12			
	35	8	115	165	
	35	6			
E. Market.....	84	30			
	1 166	16	85	140	Gate leakage.
	95	6			
E. Market.....	1 229	16			
	40	12	106	224	Pipe covered.
	60	4			
	70	6			
Case.....	1 187	20			
	48	6	113	84	
	25	16			
Exchange.....	805	24			
	20	16	110	65	8 joints covered.
	41	6			
Spicer.....	1 488	16			
	140	6	98	185	
Carroll.....	638	16			
	4	6	96	73	
	44	4			
E. Exchange...	1 501	24	106	46	
	38	6			
Center.....	1 197	6	130	111	All joints visible.
Center.....	611	6	135	145	
Park Place.....	536	6	132	117	
	7	4			
Amherst.....	554	6	135	45	
Sibly Al.....	435	6	135	189	
Wheeler.....	124	8	111	0	All visible.
	336	6			
Wheeler.....	356	6	110	64	
Wheeler.....	626	6	140	36	
Poplar.....	393	6	130	60	
Poplar Huron	1 718	6	133	103	
Newton.....	2 650	30	91	53	
Main.....	1 197	12	150	53	
	18	6			
Yale.....	727	6	121	40	
Cross.....	1 171	6	122	75	
Market.....	374	16			
	109	12	132	129	
	3	8			
	3	6			
West.....	659	6	128	67	
Andrus.....	837	6	102	60	
Johns.....	957	6	115	88	All visible.

TABLE I.—*Continued.*

Street.	Length, Ft.	Size, In.	Test Pres. Lb.	Leakage, Gallons per Day per Inch-Mile.	Remarks.
Cross	448	6	122	40	
Clark	1 463	6	93	65	Visible.
Fountain	761	6	112	44	All visible.
Nash	692	6	115	37	All visible.
Furnace	1 087	6	152	0	One half visible.
Furnace	1 233	6	150	0	
Dixon Pl	458	4	110	23	
Beaver	1 509	6	104	0	All visible.
Brown	1 489	6	97	11	All visible.
Market	1 725	12			
	75	8	118	142	All visible.
	14	6			
Woodland	385	6	125	0	All visible.
Market	967	12			
	97	10	117	176	All visible.
	50	8			
W. Market	843	12			
	26	6	110	110	
	26	4			
Thornton	942	10	126	56	
	111	6			
Newton	1 811	30			
	22	8	66	149	Covered.
	22	6			
Manchester	567	10	117	0	All visible.
W. Market	1 013	12	105	82	All visible.
	64	6			
Church	455	8	125	61	All visible.
	16	6			
W. Market	980	12	85	66	
	72	6			
State	764	16	116	23	All visible.
	75	8			
Case	1 890	30	130	47	
	57	6			
W. Market	573	12			
	55	6	77	35	
	14	8			
W. Market	2 204	12			
	143	6	118	102	All covered.
	25	8			
Valley	1 106	6	137	139	All vis. Gate leak.
	26	4			
Grant	744	8	113	11	All visible.
	108	6			
Goodwin	573	6	130	91	

TABLE I.—*Concluded.*

Street.	Length, Ft.	Size, In.	Test Pres. Lb.	Leakage. Gallons per Day per Inch-Mile.	Remarks.
Bittman.....	1 335	10	140	158	All visible.
	64	6			
	16	4			
Grant.....	1 503	8	106	105	
	38	6			
Grant.....	995	8	120	35	
	100	6			
Grant.....	996	8	113	48	
	92	6			
Maple.....	1 184	10	130	49	All visible.
	28	6			
Maple.....	967	10	130	83	All visible.
	43	6			
Thornton.....	1 774	8	97	0	
	98	6			
Bowery.....	658	6	130	25	All visible.
Forge.....	995	6	102	60	All visible.
Forge.....	1 000	6	100	102	
Hazel.....	2 240	30	112	115	14 joints calked later.
	72	6			
	31	10			Gate leakage.
	19	8			
Hazel and Adams	1 724	30	104	53	May have included section above. Some valve leakage.
	26	6			
	22	4			

SUMMARY.

Total number of original tests.....	100
Tests included in summary.....	86
Tests where all joints were exposed and no leakage exists but gate leakage was bad.....	8
Tests where joints were covered and gate leakage is known to exist, pipe accepted.....	3
Tests where pipe has not been accepted.....	3
	100

TABLE II.

TESTS OF PIPE LAID BY SUPT. OF WATER WORKS, AKRON, OHIO, 1914.

Street.	Length, Ft.	Size, In.	Test Pres. Lb.	Leakage, Gallons per Day per Inch-Mile.	Remarks.
Halsted	641	6	100	19.8	All joints covered.
Union Pl.	924	6	100	0	All joints covered.
Diagonal Rd.	2 850	10	75	133.4	All joints covered.
Crosby	1 363	6	90	15.8	All joints covered.
Ledge	570	6	120	0	All joints covered.
Roswell		6			
McNaughton		6			
Broad	2 437	6	110	90.9	All joints covered.
Ash	630	6	125	14.1	All joints covered.
Wildwood	842	6	90	99.5	All joints covered.
Charles	564	6	150	29.2	All joints covered.
First		6			
Chittenden	2 188	6	100	27.2	All joints covered.
Chittenden	580	6	100	162.0	Leak at V. stem.
Brook	681	6	125	61.4	All joints covered.
Blaine	500	6	125	0	All joints covered.
Dayton	500	8			
Hillier	707	6			
Thayer	1 632	6	125	142.5	All joints covered.
Elma	1 140	6			
Bellows	510	6			
Abel	1 134	6	115	77.0	All joints covered.
Commins	406	6	130	0	All joints covered.
Cole	910	8			
	163	6	110	55.2	All joints covered.
Curtis	700	6	110	0	All joints covered.
Parkdale	853	6	135	14.9	All joints covered.
Euclid	1 033	6	130	12.3	All joints covered.
Euclid	276	6			
	375	8	140	16.3	All joints covered.
Fuller	1 130	6			
Hart	900	6			
Fourth	550	6	100	169.4	All joints covered.
Fifth	550	10			
Howes	680	6	85	0	All joints covered.
Martin	445	6			
Fifth	340	6	80	100.3	All joints covered.
Talbot	1 767	6			
Lacroix	1 750	6	130	36.2	All joints covered.
Bank	789	6	110	16.1	All joints covered.
Euclid	1 076	8	110	170.4	24 unused services.
Silver	646	6	140	177.0	All joints covered.
Summit	1 189	8			
Summit	530	6	110	86.4	All joints covered.
Park	1 800	6			
Camp	600	6	125	56.8	All joints covered.

TABLE II. — *Continued.*

Street.	Length, Ft.	Size, In.	Test Pres. Lb.	Leakage, Gallons per Day, per Inch-Mile.	Remarks.
Fifth	1 326	10			
Chittenden	360	6	105	87.7	All joints covered.
Duane	940	6			
Hart	263	8			
Carpenter	748	6			
Edwards	303	6	125	141.8	All joints covered.
Shelby	307	6			
Garfield	1 440	8	125	42.0	All joints covered.
	100	6		84.4	All joints covered.
Campbell	750	6	135	28.9	All joints covered.
Buchtel	756	8	120		
Broadway	352	6	120	38.6	All joints covered.
Chestnut	206	6			
Pine Al.	477	6	140	124.8	All joints covered.
Ardmore	580	6	75	10.9	All joints covered.

SUMMARY.

Total number of tests made	40
Total number of tests included in summary	38

Tests were omitted because leakage exceeded specifications in initial tests. These will be repeated. All joints were covered and no definite reason can be assigned.

DISCUSSION.

THE PRESIDENT. This paper presents many new points which are of great value. I was very much interested in Mr. Bradbury's statement in regard to the importance of testing pipe lines on the second day after putting on pressure, and that he was much more successful with that method of procedure than in testing immediately after filling the line.

MR. CLARENCE GOLDSMITH. I believe that it is highly important to fill the line the day before it is tested, because it is almost impossible in ordinary work, where you are laying pipe fairly level, to avoid getting some high spots in the line, and it is with great difficulty that the air is forced out, particularly if the joints are well driven. About two weeks ago we had an experience of this kind in attempting to get 400 lb. pressure on the high-pressure

line. It was very slow work until we got rid of all the air, for there were several high spots.

But, over and above finding the leakage, I think it is equally as important to have the pressure test before the lines are accepted for use, for it is not an uncommon thing at the time of a fire for lines to rupture and to put the fire department to great disadvantage. I have in mind a city in the South, where some three months ago there was a bad fire, and among a series of accidents which happened on the works was the failure of a 12-in. line which had been laid within a year. If that line had been tested out at the time it was put in, at one and a half times the working pressure, in all probability the defect would have been found.

There is one city which, I think, is a preëminent example. That is Atlanta, Ga., where all the lines laid are tested at 300 lb. before they are filled in. That rule is strictly adhered to. When I first talked to the superintendent, Mr. William Rapp, with regard to this, I was a little skeptical. He was then laying a 20-in. line through the heart of the city, and held every joint of that line open, and subjected it to 300-lb. pressure. That was practically all the inspection he had of the pipe, as they do not have any inspectors at the foundry; but the foundry people understand that for any failure of the pipe they are directly responsible. The pressure was maintained for one hour, and every joint was gone over carefully. Of course there were a few spits of water, but the test showed a very good job indeed, and the superintendent assured me that every pipe in Atlanta is subjected to such a test.

I think the figures that the speaker gave show us very forcibly how much money we can afford to spend to keep a line open, because in many places the extra expense is comparatively small compared with the loss of the benefit which will be obtained by keeping the line open to make the test.

Mr. W. C. Hawley. There is one point in the making of a lead joint which may not be familiar to all, and that is the temperature at which the lead should be calked. I remember some twenty years ago laying a block of pipe in a hurry so that the mayor and council could see the pipe tested. The lead was calked as fast as it was run, and when the water was turned into the pipe you could have taken a shower bath at any of the joints. That

set me to thinking, and I found that the coefficient of expansion of lead is about three times that of cast iron. After that I always specified that the lead should not be calked until it was cold; and I have found a great difference in the tightness of the joints when that specification has been followed.

Incidentally, on the matter of testing pipe in the open trench, I have found that the use of leadite is very convenient, because we can test 100 or 200 ft. of pipe whenever we want to by putting in a plug and then we can cut the leadite out quickly and go ahead and lay pipe. I have done that in thickly populated districts where we couldn't leave a long length of trench open.

MR. FRANK L. FULLER. I should like to ask Mr. Bradbury if in making the test before the back-filling was done he used a temporary plug, and if so, how the air was gotten rid of.

MR. BRADBURY. We never used any temporary plugs in making the tests, on account of the interference with the progress of the work and the additional water to get rid of in the trench when the plug is removed. The general rule in the Akron tests has been to keep the trench open throughout. We have had a good deal of trouble and many complaints, but usually the people have been willing to see that it was really for their benefit that the trench should be left open, and that they should suffer a little temporary inconvenience, really very little in most cases, rather than to have leaky pipes.

The figures which I have quoted indicate plainly that a city can well afford to use a great many more gates than is customary and still be money ahead, if by so doing it can get a tight pipe line. If the difficulty in testing the pipe in the open trench is the inconvenience to the public, and it won't stand for having the trench left open, the use of more gates will largely overcome the objection. In the example which I cited, a city of 100 000 population, producing water at a cost of $25 per million gallons, can afford to spend $470 per mile of pipe to save 400 gal. per inch-mile, using a seven per cent. capitalization. It is hard to get too many gates in a pipe system, and this advantage is to be considered.

In connection with the tabulations of the Akron tests, I wish to say that in case of pipe laid by contract, it was the rule throughout that most of the joints were exposed, as covering was only done

where for some reason it was absolutely impossible to keep the trench open. I think there were not more than twenty where the entire pipe was covered. The pipe laid by city labor was covered before testing.

MR. ALLEN HAZEN. I understand that in Los Angeles all of the joints in the cast-iron pipe system are made with Portland cement and sand mortar and that it is believed in Los Angeles that the joints so made are fully as tight as could be made with lead, and they are also much cheaper and more convenient to make in the trench.

In San Francisco, the works are owned by the Spring Valley Water Company, and in one important respect the joint differs from those of the standard pipe of the New England Water Works Association and of the American Water Works Association. The difference is in the shape of the groove in the bell. The design as used was made by Mr. Herman Schusler, then chief and now consulting engineer of the company, who had previously had experience with pipes at extremely high pressures in Nevada mining camps.

In the Schusler joint the groove is reversed, so that the face nearest the end of the pipe has only a slant of one in three, while the face away from the end of the pipe slants nearly one to one. It is believed in San Francisco that it is easier to calk this joint tight, and that it stays tighter, especially when there is movement in the joint.

Mr. Schusler explained to me that it was his idea that with the flat slope toward the end the effect of calking is to expand the lead to completely fill the groove, while with the abrupt slope toward the end the effect of hard calking is to compress the lead in the cylindrical space between the end and the groove, and afterward to push the mass away from the face of the abrupt slope of the groove, leaving an opening which made the joint less solid and gave an opportunity for movement or leakage. A great many joints of actual pipes have been sawed at San Francisco to demonstrate the character of the joint and the position of the lead after calking.

Some old French works indicate that French pipe of twenty years and more ago was cast with a groove something like that in the San Francisco pipe, while Fanning's "Water-Supply Engineer-

ing," which best represents American practice of a generation ago, shows a groove with about equal slopes on both sides. Turneaure and Russell show the grooves used in several American cities some years ago, and these indicate bells in use in Chicago, Brooklyn, Providence, and St. Louis, with more or less flat slopes toward the outer end. On the other hand, the Boston pipe and the pipe of the Metropolitan Water Works had the abrupt slope toward the outer end, and this is the type that has been adopted by the standard specifications of the two associations.

In dimensions, the San Francisco groove does not differ very much from the New England standard. The peculiarity is that it is reversed.

It would be interesting if Mr. Brackett, or some one, could tell us about the Boston practice, and why the groove has its abrupt part toward the end of the bell, and why that was adopted in place of what now appears to have been the older practice.

MR. GOLDSMITH. With regard to the joint as adopted by Mr. Schusler, of the Spring Valley Water Company, and the modification of that joint as adopted by the city of San Francisco and also by the city of Boston for high-pressure mains, I will say that before that joint was developed and adopted the city of San Francisco made a very exhaustive study of the shape of the grooves in the bell; and in order to determine the effect of the driving of the lead on joints of different designs, they cast a number of hubs which were split and had ears on either side, held together by bolts, and joints of different depths were poured. Then the bell could be removed without disturbing the lead, so that one could see plainly what the effect of driving was. The joint with the New England Water Works groove reversed is practically filled by good hard driving, whereas the joint of the New England or American Water Works Association is not completely filled. And I think when you consider the thing from a practical standpoint the reason is very simple. If you have a hole that you want to tamp full of sand, the more acute the angle is, the easier the sand can be tamped into the hole. And so with lead. The lead will drive back very much more easily. The tests of the joints which were designed for the first high-pressure mains showed that even the first groove would not fill with the hardest driving. The

Boston water-works high-pressure joint consists of an outer joint with the groove reversed, and an inner one with the groove in the same position as in the American and New England Water Works joint.*

The particular reason why San Francisco went into this question was on account of the effect of earthquakes on cast-iron pipe. Having adopted cast iron as the material, they wanted to be able to lay the pipes in the area which was affected by earthquakes. For although a large portion of the city lies on the rock backbone of the peninsula, yet there are a number of old sloughs which have been filled in and now form a part of the central portion of the city near the waterfront, and when an earthquake occurs, these act exactly as a bowl of jelly, and the water pipes are pulled apart or telescoped. The pipe laid in these districts is all spigot pipe, connected by sleeves with, I believe, four inches between the ends of the pipe, and that is covered over by either a sheet of tin or copper. When an earthquake occurs, the telescopic effect occurs at that point, and the pipe simply slips into the sleeve; or if it is drawn apart, it simply pulls out. The experiments were all conducted on a line of 8-in. pipe. They put the pipe together, and after the line was made up they pulled it apart with a total movement of 2 in. They did that twelve times, and between intervals they measured the leakage, and at the end of the twelfth time the leakage of the joint was practically nothing. In other words, the joint is self-tightening.

In connection with the use of a plug, in the construction of the San Francisco system, they developed a plug which could be inserted into the barrel of the pipe, designed on the principle of an elevator plunger. Instead of using leather, their mechanical engineer used rubber, and the entire end-thrust of this plug was taken by the blocking put behind it, thus saving the pipe from any end strain whatever. When the test was over the blocking was simply knocked out and the plug was easily removed. I have a number of those plugs which we are going to use in Boston.

MR. HAZEN. Do I understand that the Schusler groove is filled solid?

MR. GOLDSMITH. In our tests we have burst the bell, and the

* JOURNAL N. E. W. W. A., *28*, 113.

outer groove is filled solid. You can see the mark. When the bell is first broken it is very easy to be seen by the eye. After the lead has been out a little while you cannot tell, but just after it is broken you can tell.

MR. HAZEN. Why wouldn't it be a good idea to reverse the groove in the standard specifications, then?

MR. GOLDSMITH. I don't know but it would.

MR. ALFRED D. FLINN. I would like, Mr. President, to ask the writer, In the standard allowance for leakage in the joints, what pressure in the main is supposed to exist, — both in the test and in general?

MR. BRADBURY. It is based on a water level 85 ft. above the height of the distributing reservoir at low water; that is, about 35 lb. more than the static head. Our experience in regard to the relation between a given pressure and defects in the joint is not very illuminating. I have not been able to find much, if any, difference with pressures up to 175 or 200 lb. In fact, I have had some cases where the same pipe leaked less under 180 or 190 lb. than it did under 100 lb. I have not yet found the explanation of that phenomenon, but I know it occurred. I believe that in any specification for ordinary service pipe — I am not now speaking of high-pressure fire lines — for any pressure up to, say, 150 lb., it is not necessary to make any difference in the specified permissible leakage on account of variation in test pressure.

MR. FLINN. A little experience we have had in an experimental way in connection with flexible joints may suggest a possible explanation of the difference in leakage in pipe lines in some instances. In making some experiments on 36-in. flexible joints we found that under pressure the joints were tighter, and on examining the joints it was observed that there was a considerable area on the spigot end of the pipe which was exposed to unbalanced pressure, thus tending to force the spigot out of the bell; in other words, producing a compression on the lead joint by pulling the pipe, as is done in some submarine lines, and forcing the lead more tightly against the surface of the spherical bell. A similar action might occur with straight bell joints under some conditions.

The specification of two gallons leakage allowed per foot of

joint in the specifications, of which the writer spoke, was for pipe lines under a pressure of about 130 lb. per sq. in. static, with a special allowance for water ram beyond that. In one contract for 48-in. pipe under that specification the contractor had much trouble in meeting the specification. The trouble originated by his doing unsatisfactory work to begin with; but after he was required to go over practically all of his joints, in some cases at the expense of digging them up, he did meet the requirements of the specifications.

In connection with the pipe line across the Narrows of New York Harbor, which is now under construction, some very interesting experiments have been made with lead joints for flexible, or spherical, jointed pipes 36 in. in diameter. First, an endeavor was made to find an alloy which, if cast into such joints, would have no shrinkage, or possibly a very slight enlargement of the metal on cooling. We found no alloy of any practical value in that line. Indeed, we did not succeed in finding any which did not have at least a little shrinkage, so that idea was given up as impractical, and the practice which we have adopted of forcing cold lead into the joint has been followed. The bell and spigot are of the type known as the Duane joint, modified. The bells are not only turned accurately, but are finished by grinding, so as to give the inside a smooth and truly spherical surface. The lead is cast in the joint space in the usual way, and then additional lead is forced, cold, into the shrinkage space by means of gib screws, through thirty-two holes in the bell, arranged in two rows of sixteen each, staggered. The lead is applied in the form of pellets, $\frac{9}{16}$-in. in diameter and $1\frac{3}{4}$ in. in length. Three pellets are forced into each of the back holes. About 20 to 22 lb. of lead are thus added to a 36-in. joint to fill up the appreciable space due to shrinkage of the lead as it cools. Joints made in this way, after several deflections of about 5 degrees in each direction, under hydrostatic test at 100 lb. pressure per sq. in., are so tight that a leak of only a drop of water will occur in the space of a minute; and some joints are absolutely tight. A mixture of lubricating grease with 10 per cent. of graphite is applied to the holes to aid flexibility of the joint. Work on this pipe line has only been begun, so that the degree of tightness of the 10 000-ft. line as a

whole cannot be told until at least a year from the present time.

I would like to inquire whether in any of the pipe lines mentioned in the paper, lead wool was used.

MR. BRADBURY. None whatever — nothing but lead.

MR. FLINN. We have used lead wool in some few difficult places with considerable advantage. In testing the effect of calking a joint, in one case we found that using a pneumatic hammer, having a pressure of probably about 60 lb. at the tool, the effect of calking was not observable beyond about five eighths to three quarters of an inch from the face of the joint, when the tool was handled by an experienced and unusually careful man.

A MEMBER. I would like to inquire of the writer of the paper if, speaking of filling the line the day before he made the test, whether he ever had any trouble on account of shifting of any of the bends. I have had two experiences, both of them pretty near the pump, on a 16-in. main, where I have filled the pipe, not for the purpose of making a test, on one day and have been called up before the next morning.

MR. BRADBURY. In the village of Grandview Heights, which is referred to in the paper, we had one bend which was blown out three times before we got it so it would stay. In the Akron work there has been a little trouble of that kind occasionally. This suggests a question which I would like to ask Mr. Goldsmith, with regard to the putting in of these temporary plugs. He spoke of bracing against the bank. We tried that in the case of one gate to be laid on rather a steep grade, so that the pressure at the bottom was necessarily rather high, and we found that nothing we could use in the way of bracing would hold the gate from pushing off. It was a 24-in. gate on a 30-in. line, and we found it would push the whole end of the trench away when the pressure was put on.

MR. GOLDSMITH. The advantage of the plugs is that they are put so far into the pipe that they can stand a pull-back of about a foot easily before they will come out; and if you have a moderately stiff soil and put a wedge in, or, rather, two wedges with their ends against the back of the trench, and have a third wedge coming between them so as to distribute part of your load on the

sides of the trench as well as the rear, up to sizes we have, that is, 20 in., we have no trouble at all. We had a contractor the other day who braced a 16-in. gate with a 2-in. plank across a masonry wall. There was no alloy in that joint; the joint was on a straight line and there was no call for it. I think you will have no difficulty in holding the plug if the man who is doing the work realizes what he has to hold.

MR. EDWARD D. ELDREDGE. I consider that it is of the greatest importance to give attention to the foundation of the pipe. Even if the pipe is all right when tested in the open trench, it is not certain that after the back-fill is put in it will not start to such an extent as to cause a leakage. I think that is a point which is often overlooked.

THE PRESIDENT. Our specifications say one-half gallon per linear foot of joint per twenty-four hours under 400 lb. pressure maintained for one hour. The critical part of that hour, so far as the contractor is concerned, is the last twenty minutes. His fate is decided then. We have not done much of it yet, two or three tests only, but have come easily within the requirements.

MR. FLINN. That is with your new type of joint?

THE PRESIDENT. Yes.

MR. DEXTER BRACKETT. I can add little if anything to what has been so well stated by the speaker, relative to leakage from water pipes. In my experience in connection with the Boston and Metropolitan supplies, I have found leakage from the mains generally within the limits given by the speaker, and I have frequently experienced difficulty in accurately determining the leakage on account of the presence of air in the pipes. The following figures give the results of leakage tests made from

Inside Diameter of Pipe in Inches.	Sum of Lengths Tested		Average Leakage Found per Lin. Ft. of Pipe in Gallons per 24 Hrs.	Average. Leakage per Lin. Ft. of Lead Joint in Gallons per 24 Hrs.
	Feet.	Miles.		
48	116 563	22.0	3.7	3.16
42	11 744	2.2	2.5	2.43
36	25 663	4.9	2.9	3.19
30	7 287	1.4	0.6	0.81
24	20 553	3.9	2.1	3.44
20	40 231	7.6	3.6	7.00
16	49 903	9.4	1.9	4.65

fifteen to twenty years ago of mains connected with the Metropolitan Water Works, tests being made soon after the pipes were laid.

The total length of the different sizes tested was 271 944 ft., and the average leakage per linear foot of lead joint per twenty-four hours was 3 gal.

Where pipes are laid in public streets it is seldom feasible to allow the pipes to remain uncovered for a sufficient length of time to allow them to be tested before the trenches are refilled.

I will ask Mr. Goldsmith to answer the question relative to the best form of joint to be used to secure water-tightness, because I believe that the city of Boston has made a number of very valuable experiments upon the form of joint, and as a result of these experiments I think they are now using joints containing a double groove. The same or a similar form of joint has been adopted for a pipe line on the Metropolitan Works where special care is being taken to secure water-tightness.

Referring to the form of groove used in the sockets of pipes on the Metropolitan Water Works, the lead grooves used on the Boston Water Works previous to 1891 were in the form of a semi-circle of $\frac{1}{4}$-in. radius, having its nearer edge placed one inch from the face of the bell.

Grooves of this design in the pipes furnished by the foundries generally took the form of an irregular depression rather than a sharp-edged circular groove, and in 1891 the form of groove was changed to the triangular form now used in Boston, and which has also been adopted by the Metropolitan Water Works and by the New England and American Water Works associations.

So far as I know, no particular thought was given to the angle made by the sides of the groove, and it is possible that the form used in San Francisco, with the short side facing the joint opening, is preferable to that adopted by the New England Water Works Association.

For pressures in excess of 100 lb., grooves in both the bell and spigot of the pipe will doubtless give a more satisfactory joint than any form of a single groove.

Regarding the effect of variation in temperature on the tightness of joints, I agree with a previous speaker that joints which

are tight when the pipes are first laid may leak a few months later if temperature changes have occurred in the mean time. On the Metropolitan Works several lines of pipe crossing rivers were laid with pipes having smooth spigot ends with a slight taper. When these pipes contract with falling temperature the joints open and cause leakage.

PROCEEDINGS.

The Thirty-Third Annual Convention.

Boston, Mass.,
September 9, 10, 11, 1914.

The Thirty-Third Annual Convention of the New England Water Works Association was held at the Copley-Plaza Hotel, Boston, Mass., September 9, 10, and 11, 1914.

The following members and guests were present:

Members.

G. H. Abbott, S. A. Agnew, J. M. Anderson, W. G. Aubrey, M. N. Baker, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, F. A. Barbour, H. K. Barrows, C. H. Bartlett, G. W. Batchelder, G. A. Benjamin, F. D. Berry, C. R. Bettes, F. E. Bisbee, A. E. Blackmer, E. M. Blake, C. A. Bogardus, George Bowers, C. L. Bowker, Dexter Brackett, E. C. Brooks, E. G. Bradley, H. E. Bryant, James Burnie, W. H. Butler, J. S. Buzby, T. J. Carmody, C. J. Callahan, J. T. Carmody, L. W. F. Carstein, E. J. Chadbourne, J. C. Chase, R. C. P. Coggeshall, M. F. Collins, H. S. Clark, F. L. Cole, F. L. Clapp, W. T. Clark, R. L. Cochran, W. R. Conard, J. E. Conley, H. R. Cooper, G. E. Crowell, F. L. Cushing, Gorham Dana, F. A. Darling, J. J. Corkery, C. E. Davis, J. C. DeMello, Jr., J. M. Diven, A. O. Doane, John Doyle, L. R. Dunn, E. R. Dyer, H. P. Eddy, E. D. Eldredge, G. C. Emerson, G. F. Evans, E. E. Farnham, B. R. Felton, J. N. Ferguson, G. H. Finneran, A. D. Flinn, R. J. Flynn, J. H. Flynn, F. F. Forbes, F. L. Fuller, Patrick Gear, H. T. Gidley, F. J. Gifford, T. C. Gleason, A. S. Glover, W. S. Garde, Clarence Goldsmith, J. M. Goodell, F. W. Gow, J. W. Graham, F. W. Green, F. H. Gunther, R. A. Hale, R. K. Hale, F. E. Hall, E. A. W. Hammatt, L. M. Hastings, W. C. Hawley, A. F. Hart, Allen Hazen, D. A. Heffernan, F. C. Hersey, Jr., D. J. Higgins, I. G. Hoagland, J. L. Howard, C. S. Howe, A. C. Howes, C. L. Howes, H. C. Jenks, C. E. Johnson, G. A. Johnson, W. S. Johnson, G. R. Jones, J. W. Kay, F. T. Kemble, Willard Kent, J. A. Kienle, Patrick Kieran, J. W. Killam, S. E. Killam, F. C. Kimball, A. C. King, G. A. King, J. J. Kirkpatrick, Morris Knowles, C. F. Knowlton, H. O. Lacount, E. S. Larned, W. F. Learned, M. B. Litch, E. J. Lonergan, E. J. Looney, W. C. Lounsbury, P. J. Lucey, D. B. McCarthy, D. A. McCrudden, F. A. McInnes, T. H. McKenzie, Thomas McKenzie, J. N. McKernan, Hugh McLean, J. A. McMurry, F. A. Marston, A. E. Martin, T. B. Martin, W. B. R. Mason, W. E. Maybury, John Mayo, J. H. Mendell, W. H. Merchant, Jr., F. E. Mer-

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ASSOCIATES.

Addressograph Co., by A. R. Hitchcock, A. L. Davis, H. C. Delaney, H. B. Phillips, Miss Molly Kowalsky, A. H. Williams, C. B. Kuisnere, and C. H. Swift; Allen & Reed, Inc., by Z. M. Jenks; American Bitumastic Enamels Co., by L. B. Darling; James Boyd & Bro., by L. Lebengood; Builders Iron Foundry Co., by G. H. Lewis, B. B. Bartlett, F. N. Connet, A. B. Coulters, and D. J. Purdie; A. M. Byers Co., by W. W. Weller, J. J. Riley, A. M. McCormack, and H. F. Fiske; Central Foundry Co., by R. W. Conrow; Chapman Valve Mfg. Co., by H. H. Cook, F. J. Radley, H. U. Storrs, W. B. Atkinson, J. J. Hartigan, J. F. Mulgrew, C. E. Pratt, V. N. Bengle, and H. M. Tupper; Darling Pump & Mfg. Co., by H. A. Synder; Dixon Crucible Co., by G. W. Hart, J. W. Gledhill, and H. A. Nealley; Eddy Valve Co., by H. A. Holmes; Electro Bleaching Gas Co., by E. D. Kingsley; *Engineering News*, by F. B. Godley and H. R. Annes; *Engineering Record*, by R. K. Tomlin, Jr., Burdette Phillips, and I. S. Holbrook; Fairbanks Company, by C. H. White and A. W. Farwell; Goulds Mfg. Co., by R. E. Hall; Hays Mfg. Co., by C. E. Mueller and F. F. Myers; Hersey Mfg. Co., by W. T. Kershaw, S. B. Greene, George McKinnon, W. A. Hersey, L. S. Barnard, and H. D. Winton; Kennedy Valve Company, by M. J. Brosnan; Johnson-Washburn Co., by J. V. E. Johnson; Leadite Company, by George McKay, J. P. McKay, and C. A. Vance; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Mfg. Co., by A. R. Taylor and G. A. Miller; Mueller Mfg. Co., by G. A. Caldwell, W. N. Fairfield, and F. B. Mueller; Multiplex Mfg. Co., by J. F. Casey; *Municipal Journal*, by S. W. Hume; MacBee Cement-Lined Pipe Co., by J. D. MacBride; National Meter Company, by J. G. Lufkin and H. L. Weston: National Tube Company, by H. T. Miller and J. E. Fleming; National Water Main Cleaning Co., by Clinton Eglee and B. B. Hodgman; Neptune Meter Co., by H. H. Kinsey,

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GUESTS.

Maine: Augusta, Wesley W. Albee; Castine, G. A. Benjamin; Lewiston, Mr. and Mrs. T. W. Kerrigan; Portland, George B. Sydleman. *New Hampshire:* Henniker, Mr. E. N. Cogswell; Nashua, Mrs. W. F. Sullivan. *Massachusetts:* Allston, Mrs. A. W. Farwell; Andover, Charles Bowman, Mrs. F. L. Cole; Arlington, Mrs. H. S. Clark, Mr. and Mrs. J. E. Minor, Robert E. Whittle; Auburndale, Mrs. Helen H. Sisk; Belmont, Mrs. C. W. Sherman, Mrs. H. L. Sherman, Mrs. E. C. Sherman, Richard W. Sherman; Boston, Mrs. H. H. Kinsey, Mrs. A. S. Glover, Mrs. G. A. Caldwell, Mrs. A. R. Taylor, Mrs. J. M. Hanlon, Mrs. A. O. Doane, Miss M. J. Cooley, Mrs. A. M. McCormack, Mrs. J. E. Cobb, Mrs. W. F. Woodburn, Mrs. F. I. Winslow, Mrs. C. F. Knowlton, Mrs. E. E. Martin, Miss A. MacDougall, Harriett Sammons, Mrs. J. A. Tilden, Lou Sanders, Mrs. H. P. White, Mr. and Mrs. J. F. Charnock, C. F. Glavin, Mrs. E. M. Shedd, Miss J. M. Ham, Mrs. E. C. Fisher, Mrs. William Wright, Mary E. Flynn, Mrs. G. C. Emerson, William E. Whittaker, Mrs. G. H. Finneran, S. M. Spencer, Mrs. Dexter Brackett, E. O. Teague, Floyd Kinsey, Ellen Kinsey, J. F. Monahan, L. H. Klugel, T. A. Moul, E. H. Milliken, Mrs. C. E. Kelly, Miss Helen Shea, Edward W. Howe, Mrs. W. H. Williams, G. H. Finnerty, Miss H. E. Howes, Francis C. Hersey, W. T. Linehan, M. J. Horrigan, B. T. Rogers, James Tilden, Jr., Lester W. Tilden, Frederic H. Fay, Harry S. Wright, Mrs. E. Milner, Miss Annie L. Lufkin, J. E. Carthy, E. H. Blume; Braintree, Mrs. W. E. Maybury; Bridgewater, Mrs. John Mayo; Brockton, Mrs. L. J. Wilber; Brookline, G. H. Francis, M.D.; Cambridge, Mrs. G. C. Whipple, Mrs. L. M. Hastings, J. H. Ripley, S. T. Barker, Howard S. Knowlton, Mrs. F. H. Hayes, James J. Scully, Dr. S. H. Osborn; Chicopee, Mrs. C. A. Bogardus; Cohasset, Mrs. D. N. Tower, Miss B. L. Tower; Danvers, Mr. and Mrs. A. W. Beckford,

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fith; Plainfield, Mrs. J. H. Blanchard, R. H. D. Blanchard; Summit, Mrs. F. C. Kimball; Trenton, Mrs. and Mrs. Alvin W. Bugbee. *Pennsylvania:* Pittsburgh, Mrs. Morris Knowles, Miss Helen Knowles, Maurice Knowles, Jr.; Philadelphia, E. M. Nichols; Steelton, Mrs. W. B. Litch; Wilkinsburg, Mrs. W. C. Hawley. *Washington, D. C.:* Wm. F. Wells, E. B. Rosa. *Wabash, Ind.:* Edwin H. Ford. *Urbana, Ill.:* H. F. Ferguson, Mrs. Wm. Ferguson. *St. Stephen, N. B.:* C. J. McKenzie. *Santiago, D. R.:* John Brown. — 255.

Wednesday, September 9, 1914.

The Convention was called to order shortly after ten o'clock by Mr. Frank A. McInnes, President, who spoke as follows:

Ladies and Gentlemen of the New England Water Works Association,— It is now my very pleasant duty to declare the thirty-third annual convention of our Association wide open, under pleasant skies and amid beautiful surroundings. A "feast of reason" has been prepared for you, which I am very sure will prove nourishing; the "flow of soul" depends upon each individual member. Keep in mind the prophecy regarding poor Jack, who worked too hard, and let us in our amusement have no "dull boys," but let each of us make sure that all others are having a thoroughly good time. Our badge should be a sufficient introduction. Above all things, let us be certain that the ladies, who have graced this convention with their presence, are remembered every moment.

In the ballroom adjoining, a notable and particularly attractive exhibit is presented by our Associate members; do not forget to visit it, and do not forget to study it, for you will be well repaid by so doing. One word of advice: Please be on time at all functions, for upon your prompt attendance largely depends the success of our convention. I welcome you all.

You are doubtless all aware of the regrettable accident which has prevented the attendance of the governor this morning; I am sure we all wish for him a speedy recovery. It now gives me particular pleasure to introduce the distinguished guest who is with us, under whom it is my privilege to serve. He is giving the city of Boston an administration which promises to be historic, for the reason that he is considering only the best interests of the entire city, and is granting special privileges to none. I have the honor to introduce the Hon. James M. Curley, mayor of Boston. [Applause.]

MAYOR JAMES M. CURLEY. *Mr. Chairman, Ladies and Gentlemen,* — In common with your presiding officer, I desire to express my regret at the inability of his Excellency the Governor and also of the Lieutenant-Governor to be with us to-day, for I realize that the most necessary element in the life of the Commonwealth, or in the life of the nation, is the constructive force such as is represented by the New England Water Works Association.

Your meeting in Boston at this time is of particular interest, not only to me, but it should be to every individual in the entire city. We have neglected in the past to give the proper amount of study and attention to our water-works development, and it is only when some such condition as that represented by the great disaster at Chelsea or at Salem visits the community that we have a proper appreciation of the value of a modern water-works system.

We are endeavoring to meet conditions as they confront us in our own municipality. We differ from European cities, inasmuch as they are very many hundreds of years older than our communities, and the materials of construction are largely what are known as non-combustible, while in our communities structures are largely of wood or other inflammable material. The city of Boston is compelled to pay an excessive insurance rate because of the class of construction that is found in the city. We are at present engaged in the installation of a high-pressure water system that in all probability will represent an outlay on the part of the municipality of not less than $2 000 000. We are carrying out the same policy that is being generally pursued by the communities that are scattered throughout New England, of changing over our water mains; and the probability is that between the high-pressure system and the regular maintenance account, the city of Boston will this year expend in the vicinity of $3 000 000 on water-works proposals direct.

We, of course, rejoice in the fact that we in all probability have, thanks to the president of your organization, and to the efficient corps of gentlemen associated with him, as good a water supply, if not the best, that is to be found in the United States. I sometimes feel that perhaps everybody takes that same view of the water supply in his own country that we in Boston have, that is it is the best, and that suggests to my mind the story of two

travelers on an ocean steamer. One said to the other, "I can tell where a man comes from by simply making a reference to fire departments." The other gentleman said, "Why, that is impossible." "Well," he said, "now there is a gentleman looking over the rail, and I will try it on him." So he walked over to the rail, and standing near the lone passenger said in a voice sufficiently loud for him to hear, "It is rather difficult to say really which city has the best fire department." Immediately the man turned around and said: "Grand Rapids, Mich., small, but very efficient." And so it is with our water supply. We believe that we have the best in the United States, and if in any measure the splendid character of the service that is received by the citizens of Boston can be traced to the President of your Association, then the entire city is obligated to the New England Water Works Association. [Applause.]

We are exceedingly pleased to have you with us, and we appreciate the advantages that accrue to the membership of an organization of this character, and to the public at large, from the interchange of ideas, and from the opportunity to make an inspection of the improvements and the progress that is being made in this particular line of human endeavor. As I looked at the exhibits in the other room, all of them intended to make life better because of you men having lived, it was impossible for me to prevent my mind from recurring to the exhibits on the other side of the ocean at the present time, and I thank God that this nation is at peace. I sincerely trust that the wish of the President of the country, and of every sincere American, may shortly be fulfilled, and that peace and prosperity and progress may come to the people on the other side of the ocean, and that America may have an opportunity to fulfill her mission and be the agent of peace throughout the entire world. [Applause.]

Mr. R. J. Thomas. I call for three cheers for Mayor Curley of Boston. [The members of the Convention rose and gave three cheers.]

Mayor Curley. I thank you very much, gentlemen.

Mr. Allen Hazen. Mr. President, we have known for a long time that the mayor is a close student, but I must say that it is a surprise to me to see how he has mastered one of the fundamental

principles of the water-works business, and how he sees the difference between what has to be done in Boston and in other American cities and that which has to be done in European cities. In Europe the buildings are usually fireproof, and the function of the water works is to distribute water; but here water must be furnished not only for domestic and manufacturing uses, but also to put out fires. That makes a fundamental difference in the whole water-works business, and the $2 000 000 that Boston must spend on the high-pressure system represents only a small part of that difference. But I think we may look forward confidently to the time when our cities also will be fireproof, and when this heavy additional load which is now put upon the water-works systems will be eliminated.

I have had the pleasure of spending some months recently in San Francisco. That city has been rebuilt since the fire, and the business district is now more nearly fireproof than that of any other city on the American continent. If the mayor has not been there, I hope he will have an opportunity to go and see what has been done, for I know that he will appreciate the great advantages in all directions growing out of the fireproof construction.

The members of this Association are always glad to come to Boston, for this is the home of the Association, and we always feel at home here and know that we are always welcome. In behalf of the members, I thank his Honor for his kind words. [Applause.]

THE PRESIDENT. Now, gentlemen, we will proceed to business, and I will ask the Secretary what he has for us.

THE SECRETARY. We have applications for membership from the following:

Ernest Wadsworth, Duxbury, Mass., water commissioner; James E. Cowper, Boston, Mass., hydraulic engineer, assistant manager of Runser & Co., Ltd., for past eight years; Horace J. Cook, Waterville, Me., assistant superintendent Kennebec Water District; Thomas C. Sheldon, Fitchburg, Mass., civil engineer and water commissioner; E. Weller Smith, Glens Falls, N. Y., superintendent water works and city engineer; L. W. F. Carstein, Long Beach, N. Y., superintendent of the Long Beach Water Company; Arthur S. Watson, Oak Bluffs, Mass., superintendent water works; Raymond C. Allen, Manchester, Mass.,

civil engineer; Charles S. Clark, Boston, Mass., member of Board of Water Commissioners, Duxbury, Mass.; Charles F. Barker, Rowayton, Conn., secretary of the Tokeneke Water Company; Edward J. Tucker, Cristobal, Canal Zone, in charge of Mt. Hope filtration plant, Panama Canal; George L. Stebbins, Seal Harbor, Me., president Seal Harbor Water Supply Company; Gordon B. Smith, Middletown, Conn., civil engineer; Carleton Scott, Woonsocket, R. I., superintendent of water works; Clifton L. Rice, Lowell, Mass., in charge of experimental work for the purification and extension of the water supply of Lowell; F. L. Clapp, Edgartown, Mass., engineer and superintendent of water works; Edward G. Bradbury, Akron, Ohio, engaged as practicing engineer in connection with water and sewerage works; W. C. Tannatt, Jr., Easthampton, Mass., town engineer and superintendent of public works; John T. Carmody, Hartford, Conn., with the Hartford water works; Walter H. Jackson, Attleboro, Mass., general manager and director of the Seaconnet Park Water Company, at Seaconnet Point, R. I.; Sam C. Waldron, East Providence, R. I., superintendent of Watchemoket Fire District, East Providence, R. I.; Edward W. Quinn, Cambridge, Mass., general superintendent Cambridge water works; John T. Corkery, Norwich, Conn., superintendent water works; Allston F. Hart, Saugus, Mass., superintendent water works; George H. Read, South Egremont, Mass., incorporator and president of the South Egremont Water Company; Walter S. Garde, Hartford, Conn., president Board of Water Commissioners; Rupert W. Wigmore, St. John, N. B., commissioner of water and sewerage; Eugene M. Byington, Boston, Mass., superintendent of construction Boston Fire Department, general hydraulic work and steam fire-engine expert; Frank J. Davis, Ansonia, Conn., superintendent of water company; William Latter, Boothbay Harbor, Me., superintendent water system; Cornelius J. Sweeney, Stoneham, Mass., superintendent of streets, water, and sewers; George H. Sargent, La Grange, Ga., city engineer and superintendent water works; Edward Drake, New Bedford, Mass., civil engineer; J. B. Warriner, Lansford, Pa., chief engineer Lehigh Coal and Navigation Company and superintendent of Panther Valley Water Company; D. H. Townley, Elizabeth, N. J., engineer water company; Clinton S. Howe, West Medway, Mass., chairman water commissioners; George T. Prince, Omaha, Neb., engaged in general water-works engineering; W. G. Aubrey, Hudson Falls, N. Y., manager of Spring Brook Water Company. — 37.

Associate: Ware Coupling and Nipple Company, Ware, Mass.; F. B. Godley, New York, N. Y., business manager *Engineering News; Municipal Journal*, New York, N. Y.; MacBee Cement-

Lined Pipe Company, Boston, Mass.; Columbian Iron Works, Chattanooga, Tenn., manufacturers of fire hydrants, valves, meter and valve boxes, sluice gates and water-works supplies; Multiplex Manufacturing Company, Berwick, Pa., manufacturers of and dealers in water-works supplies; G. Frank Uhler, of A. M. Byers Company, manufacturers of Byers wrought-iron pipe; Addressograph Company, Boston, Mass., office systems; William P. Brew, New York, N. Y., representing Westinghouse Machine Company, steam turbines, gears, pumps, etc.; W. P. Taylor Company, Buffalo, N. Y.; F. W. Shepperd, New York, N. Y., *Fire and Water Engineering*. — 11.

MR. R. C. P. COGGESHALL. I suppose all these names have been before the Executive Committee and are all properly endorsed?

THE PRESIDENT. Yes.

MR. COGGESHALL. Then I move that the Secretary be empowered to cast one vote in favor of the applicants.

The motion was adopted, and, the Secretary having cast the ballot of the Association as directed, the candidates named were declared elected members of the Association.

THE PRESIDENT. The next business on the program is the report of the Committee on Standard Specifications for Cast-Iron Pipe. I am the chairman of that committee, and I am sorry to say that the committee is unable to present a final report at this time. Several meetings have been held, and a number of informal conferences, both with a similar committee from the American Water Works Association and with different pipe manufacturers, and substantial progress has been made, but that is as far as we can go with our report to-day.

The next thing in order is the report of the Committee on Statistics of Filter Operations, Mr. George C. Whipple, chairman.

Mr. Whipple stated that the committee was not prepared to present a final report at this time, but had prepared a preliminary report, of which he would read a part. He then gave a summary of what the committee had done, and expressed the hope that they might be ready with the final report at the annual meeting. Mr. Edwin C. Brooks and Mr. Robert S. Weston spoke upon matters suggested by the report of the committee.

Mr. Allen Hazen, chairman of the Committee on Meter Rates,

gave a synopsis of the report of the committee as printed, and said that it was the hope of the committee that the report would be discussed fully, without gloves, and that the committee might be continued and given an opportunity to make its final report. After remarks by Mr. J. M. Diven, Mr. R. C. P. Coggeshall, Mr. Arthur E. Blackmer, Mr. Arthur A. Reimer, and Mr. George F. Merrill, on motion of Mr. William F. Sullivan it was voted that further discussion of the reports of both the committees on Statistics of Filter Operations and on Meter Rates be postponed until one of the winter meetings, and that meanwhile advance copies of the reports be sent to all of the members, so that an opportunity might be given for written as well as oral discussion.

On motion of Mr. R. C. P. Coggeshall it was voted that the President be authorized to appoint a committee of five to present later in the year, at the proper time, as provided by the constitution, a list of officers to be voted for for the ensuing year. In making the motion Mr. Coggshall said that he wanted it distinctly understood that the maker of the motion was not to serve on the committee.

(Recess till 2 P.M.)

At the afternoon session Mr. Frederic P. Stearns, chairman, presented a synopsis of the report of the Committee on Low Water Yields of Catchment Areas in New England, the full report of the committee being in print. The report was discussed by Mr. Allen Hazen, Mr. J. M. Diven, Mr. T. H. McKenzie, and Mr. Harold K. Barrows, and on motion of Mr. Hazen it was voted that the report be accepted.

A paper entitled, " The Construction of Dams," by Mr. A. E. Walden, superintendent and chief engineer of the Baltimore County Water and Electric Company, Baltimore, Md., having been submitted in print, was read by title.

(Adjourned to 8 P.M.)

At the opening of the evening session the Secretary read applications for membership, properly endorsed and approved by the Executive Committee, from the following persons:

H. S. Clark, Arlington, Mass., superintendent of public works; T. P. Martin, West Springfield, Mass., superintendent of the water department; W. B. R. Mason, Bound Brook, N. J., super-

intendent water works; George G. Anderson, Denver, Colo., consulting engineer; Herbert E. Bryant, Kingston, Mass., superintendent water department. — 5.

Associate: James J. Hart, Pittsburg, Pa., of Epping-Carpenter Pump Co.; Johnson-Washburn Co., Boston, Mass., pipe fittings. — 2.

On motion of Mr. Edwin C. Brooks the Secretary was directed to cast one ballot in favor of the applicants whose names he had read, and he having done so, the gentlemen were declared duly elected members of the Association.

Mr. E. G. Bradbury, Columbus, Ohio, read a paper entitled, "Allowable Leakage from Water Mains." The paper was discussed by Mr. Clarence Goldsmith, Mr. Dexter Brackett, Mr. W. C. Hawley, Mr. Frank L. Fuller, Mr. Allen Hazen, Mr. Alfred D. Flinn, and Mr. Edward D. Eldredge.

Mr. James A. McMurry, engineer in charge of income branch, water service, Boston, Mass., read a paper entitled, "Metering an Old City." This paper was discussed by Mr. Arthur A. Reimer, Mr. Francis T. Kemble, Mr. Charles W. Sherman, Mr. Daniel A. McCrudden, Mr. John A. Kienle, and Mr. Frank L. Fuller.

(Adjourned to 10 A.M., Thursday, September 10.)

THURSDAY, SEPTEMBER 10, 1914.

At the morning session on Thursday, September 10, Vice-President Sullivan presided, and Mr. Frank A. McInnes, in charge of the Boston Water Department, read a paper prepared by himself and Mr. Clarence Goldsmith, engineer high-pressure fire service, Boston, entitled, "Lessons from the Salem Fire." The paper was discussed by Mr. H. O. Lacount, Mr. Gorham Dana, Dexter Brackett, Mr. Morris Knowles, Mr. W. C. Hawley, Mr. R. C. P. Coggeshall, Mr. T. H. McKenzie, Mr. Walter O. Teague, Mr. Charles W. Sherman, Mr. Charles H. Smith, Mr. J. M. Diven, Mr. Frederic P. Stearns, Mr. Alfred D. Flinn, and Mr. Johnson. The authors of the paper also participated in the discussion, which occupied the entire morning session.

(Adjourned to 2 o'clock P.M.)

The President called the afternoon session to order and intro-

duced Mr. Burdette Phillips, an associate member, who, speaking in behalf of the McGraw Publishing Company, publishers of the *Engineering Record*, explained the company's plans for publishing a directory of water works in the United States and Canada, their reasons for undertaking the work, and the part which the company hoped the Water Works Association would take in the plan.

THE PRESIDENT. Now, gentlemen, we come to a part of our exercises which is very close to my heart, at least. We are going to hear directly from the men who are actually managing the water works and who know better than anybody else can tell them, of their difficulties, and are able to advise and assist the rest of us. I am going first to ask Mr. Forbes if he will kindly tell us what he knows about boiler troubles.

Supt. F. F. Forbes, of Brookline, Mass., read a paper on "House Boiler Troubles." The paper was discussed by Mr. John H. Flynn, Mr. Theodore H. McKenzie, Mr. D. A. Heffernan, Mr. J. Allen Butler, Mr. Edward D. Eldredge, Mr. William Naylor, and Mr. George E. Winslow.

The next paper, by Supt. Daniel J. Higgins, of Waltham, was on "Machine Calking of Lead Joints." The paper was discussed by Mr. William C. Lounsbury and Mr. Percy R. Sanders.

Supt. Patrick Gear, of Holyoke, next read a paper on "Care of Gates and Hydrants." The paper was discussed by Mr. J. M. Diven, Mr. William C. Lounsbury, Mr. John Doyle, Mr. Theodore H. McKenzie, Mr. C. Dwight Sharpe, Mr. Frank E. Merrill, Mr. Robert S. Weston, Mr. J. M. Diven, Mr. W. C. Hawley, Mr. Caleb M. Saville, Mr. Daniel A. McCrudden, Mr. P. R. Sanders, and Mr. Herbert E. Bryant.

Next followed a paper by Supt. William F. Sullivan, on "Water Uses Difficult to Control," the paper being discussed by Mr. W. C. Hawley, Mr. Francis T. Kemble, Mr. James A. McMurry, Mr. Arthur A. Reimer, and Mr. Lewis P. Sawin.

(Recess till 8 o'clock P.M.)

At the evening session Dr. E. B. Rosa, chief physicist, Bureau of Standards, Department of Commerce, Washington, D. C., read a paper on Electrolysis. The discussion was participated in by Mr. Robert S. Weston, Mr. Francis T. Kemble, Mr. W. C. Lounsbury, Mr. Arthur A. Reimer, Mr. Charles W. Sherman,

Mr. W. C. Tannatt, Jr., Mr. Morris Knowles, Mr. William F. Sullivan, and Mr. J. M. Diven.

George W. Batchelder, Water Commission, Worcester, Mass., read a paper on "The Automobile as an Efficiency Agent in Water-Works Management."

A description of the new water purification plant of Miraflores, Canal Zone, submitted in print by Mr. George M. Wells, division engineer, Gatun, was read by its title.

(Adjourned to 10 A.M., Friday, September 11.)

FRIDAY, SEPTEMBER 11, 1914.

The President, in accordance with a vote of the Association at the first meeting, appointed the following committee to nominate officers for the ensuing year for the Association:

Chairman, Mr. Dexter Brackett, Boston; Mr. F. F. Forbes, Brookline; Mr. E. C. Brooks, Melrose; Mr. A. E. Martin, Springfield; Mr. F. W. Gow, Medford.

The first paper of the session was read by Mr. Frank E. Merrill, of Somerville, on "Public Watering Stations," Mr. Merrill presenting with his paper a model of the watering station being used in an attempt to prevent waste of water and curb the spread of glanders among horses. The paper was discussed by Commissioner Fred F. Walker, of the Department of Animal Industry in Massachusetts; by Dr. Francis H. Rowley, of the Massachusetts Society for the Prevention of Cruelty to Animals; and by the following members of the Association: Mr. Carleton E. Davis, Mr. Frank L. Fuller, Mr. Percy R. Sanders, Mr. William C. Lounsbury, and Mr. John H. Flynn.

Supt. D. A. Heffernan, of Milton, Mass., next read a paper on "Low Water Consumption in Milton, Mass." The paper was discussed by Mr. W. A. Hawley and Mr. J. M. Diven.

The final paper of the convention was contributed by Supt. Edward D. Eldredge, of Onset, Mass., the subject of the paper being "The Use of the Magnetic Dipping Needle in Locating Pipes and Gates." The paper was discussed by Mr. Lew[illegible] M. Bancroft, Mr. J. M. Diven, Mr. Frank L. Fuller, Mr. I[illegible]ert E. Bryant, Mr. H. T. Sparks, Mr. Charles H. Tuttle.

The chairman of the Exhibition Department at this time pre-

sented his report to the convention, and it was read by Vice-President Sullivan, as follows:

BOSTON, September 11, 1914.

MR. F. A. MCINNES, *President,*
New England Water Works Association,
BOSTON, MASS.

Dear Sir, — We herewith submit our report for the thirty-third annual convention of the New England Water Works Convention, held at the Copley-Plaza Hotel, Boston, September 9, 10, and 11, 1914.

In doing so I wish to thank Messrs. Harrison, Finneran, Brosnan, and Mulgrew, for their hearty coöperation in the work of this committee; the the Associate members, who spared no expense in providing the grand display of water-works equipment and tools; the management of the Copley-Plaza Hotel, and their assistants, for the use of their grand ball room, and willing responses to our various requirements, thus being enabled to do our share in making this the banner convention.

We wish to thank the Water Departments of the Cities of Boston, Somerville, and Holyoke for their response to the invitation we extended to the Active members to join in the exhibit, and hope that this feature will show a greater development at future meetings.

We went to a large expense in arranging the Exhibit Hall, but this has all been taken care of by the exhibitors, according to their share in the space.

I have the honor to present to you the following list of exhibitors:

A. P. Smith Manufacturing Company, The Leadite Company, Thomson Meter Company, Builders' Iron Foundry, Multiplex Manufacturing Company, H. Mueller Manufacturing Company, Joseph Dixon Crucible Company, *Engineering News*, Electro Bleaching Company, Chadwick Boston Lead Company, MacBee Cement-Lined Pipe Company, Ware Coupling and Nipple Company, The Fairbanks Company, Water Works Equipment Company, Henry R. Worthington, R. D. Wood & Co., W. R. Taylor Company, National Tube Company, S. E. T. Valve and Hydrant Company, Hays Manufacturing Company, Kennedy Valve Company, G. Frank Uhler, Neptune Meter Company, Rensselaer Valve Company, Lead-Lined Iron Pipe Company, Ludlow Valve Manufacturing Company, National Meter Company, National Water Main Cleaning Company, Pittsburg Meter Company, *Municipal Journal*, Chapman Valve Manufacturing Company, Addressograph Company, American Bitumastic Enamels Company, Ross Valve Manufacturing Company, Union Water Meter Company, *Engineering Record*, James Boyd & Bro., Inc., *Fire and Water Engineering*, Hersey Manufacturing Company, Eddy Valve Company, Standard Cast-Iron Pipe and Foundry Company, The Pitometer Company, The Westinghouse Machine Company, The Goulds Manufacturing Company, Simpson Brothers Corporation, City of Boston, City of Somerville, City of Holyoke; making a total of 45 Associates and 3 Active members.

The Exhibit Hall is still open, and we hope that those who have not already done so will spend some time with us before leaving for the afternoon excursion.

Respectfully submitted,

WM. F. WOODBURN, *Chairman.*

VICE-PRESIDENT SULLIVAN. If there is no further business, this is the close of what I believe was the best convention we have ever held, or the equal of any convention we have ever held. I trust you have all been profited by the convention and will continue enjoying the further program of the afternoon and evening. I want to call upon the President, here, to make his final bow. He pretends he hasn't done anything, but I tell you he has been working night and day on it.

THE PRESIDENT. Gentlemen, I don't see that there is anything at all for me to do, but I expressed great pleasure in calling the convention open; I don't like to express great pleasure in calling it closed, but my duty is now, I think, nothing more than to state that the convention is over. I hope you have all enjoyed yourselves and been profited.

Upon motion, the convention adjourned.

A trip to Nantasket Beach occupied the afternoon and evening.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at Copley-Plaza Hotel, Boston, Mass., September 9, 1914.

Present, President Frank A. McInnes, and members William F. Sullivan, Robert J. Thomas, Samuel E. Killam, Willard Kent, Lewis M. Bancroft, and George A. King.

The following applications were received and recommended for membership:

Members: Ernest Wadsworth, secretary Board of Water Commissioners, Duxbury, Mass.; James E. Cowper, manager Rumsey & Co., Ltd., Boston, Mass.; Horace H. Cook, assistant superintendent Kennebec Water District, Waterville, Me.; Thomas C. Sheldon, water commissioner, Fitchburg, Mass.; E. Weller Smith, superintendent water works, Glens Falls, N. Y.; L. W. F. Carstein, superintendent water company, Long Beach, N. Y.; Arthur S. Watson, superintendent water works, Oak Bluffs, Mass.; Raymond C. Allen, civil engineer, Manchester, Mass.; Charles S. Clark, treasurer Duxbury Fire and Water District, Duxbury, Mass.; Charles F. Barker, secretary Tokeneke Water Co., Rowayton, Conn.; Edward J. Tucker, in charge Mt. Hope Filtration Plant, Panama Canal, Cristobal, C. Z.; George L. Stebbins, president Seal Harbor Water Supply Co., Seal Harbor, Me.; Gordon Z. Smith, superintendent water works, Middletown, Conn.; Carleton Scott, superintendent water works, Woonsocket, R. I.; Clifton L. Rice, sanitary engineer Lowell Water Works, Lowell, Mass.; Edward G. Bradbury, engineer in charge improved water works, Akron, Ohio; W. C. Tannatt, Jr., engineer and superintendent public works, Easthampton, Mass.; John T. Carmody, water commissioner, Hartford, Conn.; Walter H. Jackson, general manager Seaconnet Park Water Co. (R. I.), Providence, R. I.; Sam C. Waldron, superintendent Watchemoket Fire District, East Providence, R. I.; Edward W. Quinn, superintendent water works, Cambridge, Mass.; John J. Corkery, superintendent water works, Norwich, Conn.; Allston F. Hart, superintendent water works, Saugus, Mass.; George H. Read, president South Egremont Water Co., South Egremont, Mass.; Walter S. Garde, president water commissioners, Hartford, Conn.; Rupert W. Wigmore, water commis-

sioner, St. John, N. B.; Eugene M. Byington, superintendent construction Boston Fire Department, Boston, Mass.; Frank J. Davis, superintendent water company, Ansonia, Conn.; William Latter, superintendent water works, Boothbay Harbor, Me.; Cornelius J. Sweeney, assistant superintendent, Stoneham, Mass.; George H. Sargent, superintendent water works, LaGrange, Ga.; Edward Drake, civil engineer, New Bedford, Mass.; J. B. Warriner, superintendent water company, Lansford, Pa.; D. H. Townley, engineer Elizabethtown Water Co., Elizabeth, N. J.; Clinton S. Howe, chairman water commissioners, West Medway, Mass.; George T. Prince, chief engineer, Metropolitan Water District of the City of Omaha, Omaha, Neb.; W. G. Aubrey, manager Spring Brook Water Co., Hudson Falls, N. Y.; W. B. R. Mason, superintendent water works, Bound Brook, N. J.; T. P. Martin, superintendent water department, West Springfield, Mass.; H. S. Clark, superintendent public works, Arlington, Mass.; George G. Anderson, consulting engineer, Denver, Colo.; Herbert E. Bryant, superintendent water works, Kingston, Mass. — 42.

Associate: Fire and Water Engineering, New York, N. Y.; Ware Coupling & Nipple Co., Ware, Mass.; *Engineering News*, New York, N. Y.; *Municipal Journal*, New York, N. Y.; MacBee Cement-Lined Pipe Co., Boston, Mass.; Columbian Iron Works, Chattanooga, Tenn.; Mutiplex Manufacturing Company, Berwick, Pa.; A. M. Byers Company, Boston, Mass.; Addressograph Company, Boston, Mass.; William P. Brew, New York, N. Y.; W. P. Taylor Company, Buffalo, N. Y.; Johnson-Washburn Co., Boston, Mass.; Epping-Carpenter Pump Co., Boston, Mass. — 13.

Thirty-two members were reinstated.

Adjourned.